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Heart of Texas Council of Governments Ozone Advance Action Plan 2016 Update

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CONTENTS

LIST OF ACRONYMS AND ABBREVIATIONS V

EXECUTIVE SUMMARY 1

1.0 INTRODUCTION 3

1.1 Ozone Air Quality: Background 3

1.2 Waco and the Heart of Texas Region 5

2.0 CONCEPTUAL MODEL OF OZONE FORMATION IN THE HOTCOG AREA 8

2.1 Attainment Status and Recent Ozone Trends 8

2.2 Emissions 13

2.2.1 Emissions Summary 13

2.2.2 On-Road Mobile Emissions 15

2.2.3 Off-Road Mobile Emissions 15

2.2.4 Area Source Emissions 16

2.2.5 Biogenic Emissions 20

2.2.6 Point Source Emissions 21

2.2.7 Relative Importance of NOx and VOC Emissions in Ozone Formation 29

2.3 Effects of Weather on Ozone Formation in the HOTCOG Area 30

2.4 Ozone Modeling 34

3.0 STAKEHOLDER INVOLVEMENT 40

3.1 HOTCOG Air Quality Advisory Committee 40

4.0 DESCRIPTION OF MEASURES AND PROGRAMS 41

4.1 Participation in TCEQ Rider 7/8 Program 41

4.1.1 Technical Studies Carried out Under the TCEQ Rider 7/8 Program 41

4.1.2 Emissions Reduction Measure: Gas Compressor Engine Retrofits 42

4.1.3 Emissions Reduction Measure: Municipal Fleet Diesel Engine Retrofit/Replacement ... 43

4.1.4 Emissions Reduction/Public Outreach Measure: Bicycle Rack Installation Program ... 47

4.1.5 Public Outreach Programs 49

5.0 REFERENCES 52

TABLES

Table 1-1. 10 fastest growing cities in Texas2010-2014. 7

Table 2-1. 2006 and 2012 NOx emissions for power plants in the HOTCOG 6-county area. 24

Table 2-2. Summary of ozone season day facility-wide NOx emissions for Tradinghouse and Lake Creek for Luminant Realistic Emissions Scenarios. Simple cycle is abbreviated SC and combined cycle is abbreviated CC). 27

Table 2-3. Summary of daily maximum 8-hour average (MDA8) ozone impacts at the Waco Mazanec monitor (CAMS 1037) and throughout the 4 km domain for the Luminant Realistic Emissions Scenarios. Simple cycle is abbreviated SC and combined cycle is abbreviated CC). 27

Table 2-4. VOC/NOx ratios for McLennan County and the HOTCOG 6-County Area. 30

Table 3-1. HOTCOG AQAC membership. 40

Table 4-1. BIke rack locations and usage. 48

FIGURES

Figure 1-1. Waco Mazanec (CAMS 1037) monitor location (black star). Urban areas are shaded and their color indicates population as of 2012. The HOTCOG 6-county area is outlined in green and interstate highways are shown in blue. 5

Figure 1-2. Population of HOTCOG Area Counties for 2010 and estimated population for 2014 based on U.S. Census data from http://quickfacts.census.gov/qfd/states/48/48309.html. 6

Figure 1-3. Texas population growth from 2000-2010. Figure from Texas Tribune based on U.S. Census data. http://www.texastribune.org/library/data/census-2010/. 7

Figure 2-1. Waco Mazanec CAMS monitor location. Adaptation of TCEQ figure from http://gis3.tceq.state.tx.us/geotam/index.html, accessed December 15, 2013. Blue circles indicate the locations of ozone monitors. 9

Figure 2-2. Trends in annual 4th highest daily maximum 8-hour ozone values (upper panel) and design values (lower panel) at the Waco Mazanec monitors in McLennan County. The dashed red line indicates the 2008 75 ppb ozone standard and the 2015 70 ppb ozone standard. All data have been validated by the TCEQ. 10

Figure 2-3. Number of days with MDA8>70 ppb at the Waco (CAMS 1037) monitor during 2007-2015. 11

Figure 2-4. Number of days during each month with MDA8>70 ppb at the Waco (CAMS 1037) monitor during the period 2007-2015. 12

Figure 2-5. Number of days with MDA8>70 ppb by day of week at the Waco (CAMS 1037) monitor during the period 2007-2015. 12

Figure 2-6. Number of high ozone days by day of week at the Waco (CAMS 1037) monitor during the period 2007-2015 normalized by number of days per week in each category. 12

Figure 2-7. Emissions summaries for 2006 and 2012. 14

Figure 2-8. 2012 HOTCOG 6-county area anthropogenic NOx emissions (left panel) and VOC emissions (right panel). 14

Figure 2-9. 2012 HOTCOG anthropogenic NOx (left panel) and VOC (right panel) emissions by county. 15

Figure 2-10. Contribution of oil and gas emissions to 2012 HOTCOG total area source emissions. 17

Figure 2-11. 2012 HOTCOG area oil and gas NOx (left panel) and VOC (right panel) emissions source category breakdown. 17

Figure 2-12. Texas oil and gas well locations as of January 2014. TCEQ figure from http://www.tceq.state.tx.us/assets/public/implementation/barnett_shale/bs_images/txOilGasWells.png. Black circle indicates the location of the HOTCOG 6-county area. 18

Figure 2-13. HOTCOG area oil and gas well count trends. 19

Figure 2-14. HOTCOG area natural gas (left panel) and liquid hydrocarbon (sum of oil and condensate production) production trends. 19

Figure 2-15. 2012 ozone season day total anthropogenic and biogenic VOC emissions by county. 21

Figure 2-16. 2012 NOx emissions from point sources in the 6-County HOTCOG area for sources with NOx emissions ≥ 0.1 tpd. Area of circle is proportional to the NOx emissions rate. 23

Figure 2-17. New and proposed EGUs in McLennan County. Filled orange circles with black dot in center show location of currently operating Sandy Creek facility and locations of permitted/proposed EGUs at the Tradinghouse and Lake Creek facilities. Yellow arrows indicate their respective distances from the Waco Mazanec (CAMS 1037) monitor, which is shown as a red filled circle. 26

Figure 2-18. HOTCOG area total ozone season day point source emissions for 2006, 2008, and 2010. 29

Figure 2-19. Waco wind roses for morning (upper panels) and afternoon (lower panels) on all days (left panels) and days with MDA8≥75 ppb (right panels). 32

Figure 2-20. Inter-state back-trajectories (based on 5-day HYSPLIT back-trajectories initiated at 1 km AGL) during 2007-2012 for the 17 high ozone days at CAMS 1037. The green star denotes the location of the Waco monitor. 33

Figure 2-21. TCEQ 36/12/4 km CAMx nested modeling grids for the Texas ozone modeling of June 2012. 36 km grid is outlined in black. The 12 km grid outlined in blue, and the 4 km grid is outlined in green. TCEQ figure from http://www.tceq.texas.gov/airquality/airmod/rider8/modeling/domain. 35

Figure 2-22. Comparison of contributions to the episode maximum 8-hour ozone at the Waco Mazanec monitor during the June 2006 and June 2012 episodes....................36

Figure 2-23. Comparison of contributions to the episode average 8-hour ozone at the Waco Mazanec monitor during the June 2006 and June 2012 episodes....................36

Figure 2-24. Episode average contribution to the daily maximum 8-hour average ozone at the location of the Waco Mazanec monitor. 37

Figure 2-25. Episode maximum contribution to Waco Mazanec monitor ozone from HOTCOG 6-county area emissions for the June 2012 episode (solid bars) and June 2006 episode (cross hatched bars). 39

Figure 2-26. Episode average contribution to Waco Mazanec monitor ozone from HOTCOG 6-county area emissions June 2012 episode (solid bars) and June 2006 episode (cross hatched bars). 39

Figure 4-1. Holes bored into the engine blocks of the two replaced vehicles (upper panels) and severed frame rails in the two replaced vehicles (lower panels). 44

Figure 4-2. Specification sheet for the 2011 model year trucks used to replace each of the two 1998 HDDV that were replaced and scrapped during HOTCOG’s HDDV emissions reduction project. 46

Figure 4-3. Bike racks selected for use in HOTCOG counties. 47

Figure 4-4. Breathe Easy Waco website. 50

Figure 4-5. Air-quality bus wrap on a City of Waco Public Transportation Bus....................51

LIST OF ACRONYMS AND ABBREVIATIONS

AQAC	HOTCOG Air Quality Advisory Committee
BC	Boundary condition
CAMS	Continuous Air Monitoring Station
CAMx	Comprehensive Air Quality Model with Extensions
CC	Combined cycle
CEM	Continuous emissions monitor
CO	Carbon monoxide
CTG	Combustion turbine generator
DFW	Dallas-Fort Worth
DV	Design value
DVs	Design values
EGU	Electric generating unit
EPA	Environmental Protection Agency
HOTCOG	Heart of Texas Council of Governments
Hr	Hour
HRSG	Heat Recovery Steam Generator
IC	Initial conditions
K	Degrees Kelvin
kW	Kilowatt
MDA8	Daily maximum 8-hour average
MOVES	Motor Vehicle Emissions Simulator
MW	Megawatt
NAA	Non-Attainment Area (for the ozone NAAQS)
NAAQS	National Ambient Air Quality Standard
NNA	Near non-attainment area
NO	Nitric oxide
NO_2	Nitrogen dioxide
NOx	Oxides of nitrogen
NSR	New Source Review
O_3	Ozone
OSAT	Ozone Source Apportionment Tool
OSD	Ozone season day
ppb	Parts per billion
SC	Simple cycle
SCC	Source classification code
SIP	State Implementation Plan (for the ozone NAAQS)
SO_2	Sulfur dioxide
STARS	State of Texas Air Reporting System
STG	Steam turbine generator
TCEQ	Texas Commission on Environmental Quality
Ton	English short ton (2000 pounds)
tpd	Tons per day

tpy	Tons per year
VOC	Volatile organic compound
WRF	Weather Research and Forecasting Model
yr	Year

EXECUTIVE SUMMARY

The Heart of Texas Council of Governments (HOTCOG) is participating in the U.S. EPA's Ozone Advance Program[1] on behalf of the region surrounding Waco, Texas. HOTCOG represents the six Texas counties of McLennan, Bosque, Hill, Falls, Limestone and Freestone. The Texas Commission on Environmental Quality (TCEQ) operates a Continuous Air Monitoring Station (CAMS) in McLennan County, and ozone measurements from this site, Waco Mazanec (CAMS 1037), are used to determine attainment of the National Ambient Air Quality Standard (NAAQS) for ozone. As of January 2016, the 8-hour ozone design value for the Waco Mazanec (CAMS 1037) monitor is 67 parts per billion (ppb), which is lower than the 70 ppb 2015 ozone NAAQS.

Ozone forms in the atmosphere from emissions of ozone precursors, mainly nitrogen oxides (NOx) and volatile organic compounds (VOC.) High ozone in the HOTCOG area typically occurs on days when local temperatures exceed 90°F, wind speeds are low, and wind directions range between north-northeasterly clockwise through south-southeasterly. These wind directions are favorable for transport of polluted air masses of continental origin into the HOTCOG area. High ozone days in the HOTCOG area are generally characterized by high incoming background ozone levels plus a far smaller contribution from local emissions sources. Although the ozone contribution from local sources is relatively small in the HOTCOG area, some ozone reductions are possible via reductions in local ozone precursor emissions.

The HOTCOG area's NOx emission inventory is dominated by emissions from power plants, motor vehicles, agricultural equipment and oil and gas exploration and production equipment. VOC emissions in the HOTCOG area are dominated by natural (biogenic) sources such as trees and vegetation rather than human activities. The abundance of biogenic VOC ensures that there is always enough VOC available to form ozone so that the amount of ozone formed is determined by the amount of anthropogenic NOx emissions. HOTCOG's analyses of the area's ambient data, NOx and VOC emission inventories and photochemical modeling are consistent in showing that ozone formation in the 6-county HOTCOG area is limited by the amount of available NOx. Therefore, local emission control strategies are focused on reducing NOx.

In 2010, the HOTCOG Air Quality Advisory Committee (AQAC) was formed in response to the Waco area's inclusion in the Texas Rider 7/8 Program for ozone Near Nonattainment Areas. The AQAC includes representatives from local government, industry, the TCEQ, EPA, and private citizens. Ramboll Environ provides the AQAC with technical expertise on ozone air quality and precursor emissions. The AQAC has worked vigorously to study local ozone air quality and to develop voluntary programs that improve air quality while protecting the regional economy. The AQAC is implementing the following measures and programs in order to reduce ozone in the HOTCOG area:

- Retrofit/replacement of municipal fleet heavy-duty diesel engines

[1] http://www3.epa.gov/ozoneadvance/

- Bicycle parking rack installation with monitoring to document utilization
- Public outreach activities including:
    - Public web site with ozone air quality forecasts, information on ozone and specific actions citizens can take to improve air quality as well as contact information for citizens who would like to become more involved in addressing local air quality issues
    - Facebook page on ozone air quality that provides high ozone day alerts and actions citizens can take to reduce ozone
    - Air quality-themed signage for public buses

As part of its participation in the EPA's Ozone Advance Program, HOTCOG prepared an Ozone Action Plan and submitted it to EPA in July, 2014. In the present document, we update the HOTCOG Ozone Advance Action Plan with new technical analyses and provide information on current and planned emission reductions. The Action Plan summarizes our understanding of ozone formation in the HOTCOG area and outlines measures being taken to reduce local ozone levels. The schedule for implementation of each measure/program is provided as well as the means of verification of emissions reductions, where applicable.

1.0 INTRODUCTION

The Heart of Texas Council of Governments (HOTCOG) is participating in the U.S. EPA's Ozone Advance Program on behalf of the region surrounding the Waco, Texas area. HOTCOG represents the 6-county area consisting of McLennan, Bosque, Hill, Falls, Limestone and Freestone Counties and is an organization of local governments working together voluntarily to solve mutual problems and plan for the future of the area. HOTCOG has over 80 member governments made up of counties, cities, school districts, community colleges, and special districts, and was established in 1966. HOTCOG's responsibilities include:

- Planning for area development,
- Implementing regional plans or recommendations,
- Contracting with members to provide certain services,
- Providing review and comment on proposals seeking federal and state financial assistance,
- Implementing grant services from federal and state programs, and
- Administrative and fiscal agent for the Heart of Texas Workforce Development Board.

More information on HOTCOG may be found at http://www.hotcog.org/default.aspx.

As part of its participation in Ozone Advance, HOTCOG developed an Ozone Action Plan and submitted it to EPA in July, 2014. The Action Plan gives an overview of ozone air quality and describes the 6-county HOTCOG region (Section 1), summarizes our understanding of ozone formation in the HOTCOG area (Section 2) and outlines measures being taken to reduce 6-county area ozone levels (Sections 3 and 4). In Section 2, we discuss the HOTCOG area's emission inventory of ozone precursors and summarize analyses of ambient monitoring data and photochemical modeling that informed the selection of emissions control strategies. Stakeholder involvement is discussed in Section 3. Finally, in Section 4, we describe the emissions reductions measures and/or programs that have been and will be implemented in the 6-county area. The schedule for implementation of each measure/program is shown as well as the responsible party and means of verification of emissions reductions, where applicable. Plans described in this Ozone Action Plan are effective through January, 2017.

1.1 Ozone Air Quality: Background

Ozone is the main ingredient in photochemical smog. Ozone affects human lung function, increasing the prevalence and severity of asthma and bronchitis, and damages vegetation. The U.S. EPA sets a National Ambient Air Quality Standard (NAAQS) for ozone in order to protect public health and the environment. The NAAQS is based on health impacts for sensitive groups and there are economic penalties for areas that fail to attain it.

Under the Clean Air Act, the EPA is required to review the NAAQS periodically. EPA's most recent review of the ozone standard was finalized on October 1, 2015. On October 1, the EPA lowered the 8-hour ozone NAAQS from the 75 ppb value set in 2008 to a more stringent value of 70 ppb. The EPA expects to issue detailed guidance on the designation process in early 2016, but has indicated that attainment designations for the 2015 NAAQS will be based on 2014-2016 data[2]. State recommendations for designations of attainment and nonattainment areas are due to EPA by October 1, 2016 and EPA will finalize designations by October 1, 2017.

The Texas Commission on Environmental Quality (TCEQ) operates a Continuous Air Monitoring Station (CAMS) in McLennan County at the Texas State Technical College (TSTC) Waco Airport. Ozone measurements made at the Waco Mazanec (CAMS 1037) monitoring station determine whether the HOTCOG area is in compliance with the ozone NAAQS. In 2012, the HOTCOG area was designated as being in attainment of the 75 ppb 2008 NAAQS. At the end of the 2015 ozone season, the Waco monitor had a design value of 67 ppb, which is in compliance with the 70 ppb 2015 ozone NAAQS. Although the current design value is lower than the NAAQS, it is within 3 ppb of the 70 ppb standard. Because failure to comply with the NAAQS can adversely affect public health and inhibit economic development, ozone air quality planning remains critical for the HOTCOG area.

Ozone is not emitted directly into the atmosphere, but forms from nitrogen oxides (NOx) and volatile organic compounds (VOC) in the presence of sunlight. NOx and VOC are emitted by both natural processes and human activities. Conditions that favor the formation of ground-level ozone are strong sunlight, high temperatures, and high precursor (NOx and VOC) concentrations. High precursor concentrations in the atmosphere occur when emissions are large and/or weather conditions allow precursors to accumulate. When winds are calm and the atmosphere is stable, emitted precursors do not disperse and are available for ozone formation. On the other hand, if the atmosphere is unstable, ozone and precursors can be transported aloft away from the ground, and if winds are brisk, emitted pollutants are transported away from the area so that ozone does not build up.

Ozone is removed from the atmosphere by chemical reactions, photolysis (destruction by sunlight), deposition onto surfaces, and uptake by plants. Ozone has a lifetime of several days to weeks at ground level; this lifetime is long enough to allow ozone to be transported thousands of miles. At any given location, therefore, measured ozone is partly due to a contribution from local emissions and partly due to transported ozone, which is often referred to as background ozone. High background ozone exacerbates local ozone problems, but is not a necessary condition for an area to have high ozone. Ozone problems solely from transport can occur, but are rare. Regional and national emissions control measures such as the Federal vehicle emissions standards aim to reduce the contribution from transported ozone.

In order to reduce ozone in a given area, the ozone problem must be studied to determine the relative importance of local emissions and transported ozone. Photochemical modeling is used to assess the magnitude of the local and transported contributions. If local ozone precursor emissions are shown to contribute to ozone levels, then local emissions control measures can

[2] http://www3.epa.gov/ozonepollution/pdfs/20151001fr.pdf

be developed. The Ozone Advance Program was developed to assist areas in developing local emissions control strategies designed to reduce ozone.

1.2 Waco and the Heart of Texas Region

The HOTCOG area lies on the central Texas plain between the major metropolitan areas of Dallas-Fort Worth to the north and Austin to the south. A map of the area is shown in Figure 1-1. The six HOTCOG counties together occupy an area of 5,611 square miles. The region is relatively flat, with the highest terrain reaching a height of approximately 300-400 meters. Two major interstate highways, I-35 and I-45, pass through the area. These highways connect the Dallas-Fort Worth area with Austin and Houston to the south and are major thoroughfares.

The population in the HOTCOG area is concentrated in the City of Waco. There are smaller towns throughout the area (Figure 2-1), but much of the area in all six counties is rural land.

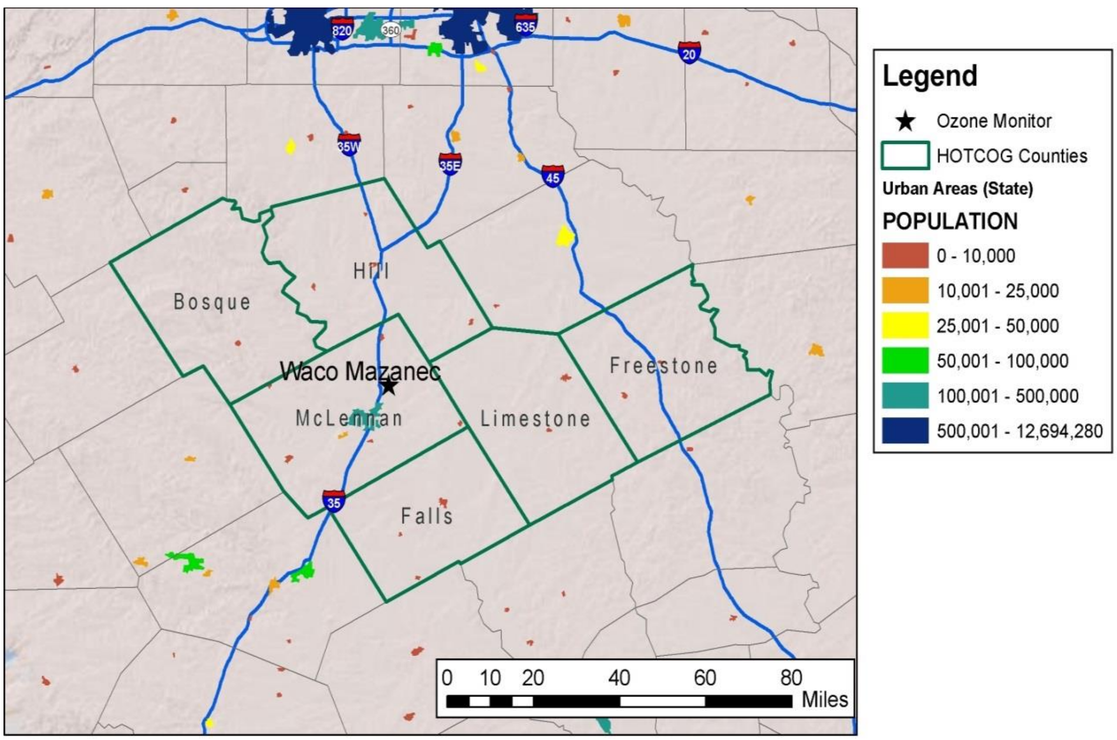

Figure 1-1. Waco Mazanec (CAMS 1037) monitor location (black star). Urban areas are shaded and their color indicates population as of 2012. The HOTCOG 6-county area is outlined in green and interstate highways are shown in blue.

Population estimates for 2014[3] (Figure 1-2) indicate that McLennan County had a population of 243,441, which is 68% of the population of the entire HOTCOG 6-county area (356,344). During the 2010-2014 period, HOTCOG counties saw small reductions in population ranging from -0.3 to -4.9% except for McLennan and Limestone Counties, which saw population growth of 3.6%

[3] http://www.census.gov/quickfacts/

and 0.6%, respectively (Figure 1-2). During the period 2000-2010, all of the HOTCOG counties saw moderate (6-11%) growth in population except for Falls County, which had a slight decrease in population (-4%) (Figure 1-3).

Figure 1-3 shows that urban areas to the north, south, southeast and southwest of the HOTCOG counties had significant (>20%) growth in population from 2000 to 2010. The Dallas-Fort Worth, Houston, San Antonio and Austin areas all had two or more counties with >40% growth and these areas are frequently upwind of the HOTCOG area on high ozone days (see Section 2 of this document and McGaughey et al., 2010a; 2012). Table 1-1 shows the 10 fastest-growing cities in Texas during 2010-2014. Cedar Park, Georgetown, Pflugerville are suburbs of the Austin area and lie south of the Waco area. Among large cities (population > 500,000), Austin was the fastest-growing city in the U.S. during 2010-2014, with 15.5% growth. In summary, the HOTCOG area has had modest population growth in recent years, while surrounding areas have undergone much more rapid growth.

The HOTCOG area overlies productive oil and natural gas fields. There are a large number of natural gas wells in Limestone and Freestone County that access conventional natural gas reservoirs, while Hill County marks the southernmost extent of the Barnett Shale natural gas development. There is also oil production in McLennan County, but the number of oil wells is relatively small.

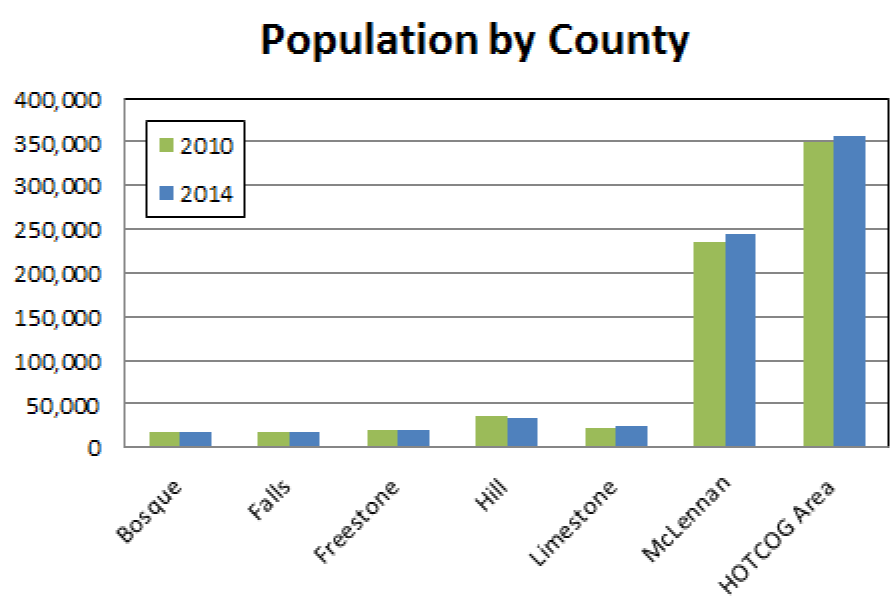

Figure 1-2. Population of HOTCOG Area Counties for 2010 and estimated population for 2014 based on U.S. Census data from http://quickfacts.census.gov/qfd/states/48/48309.html.

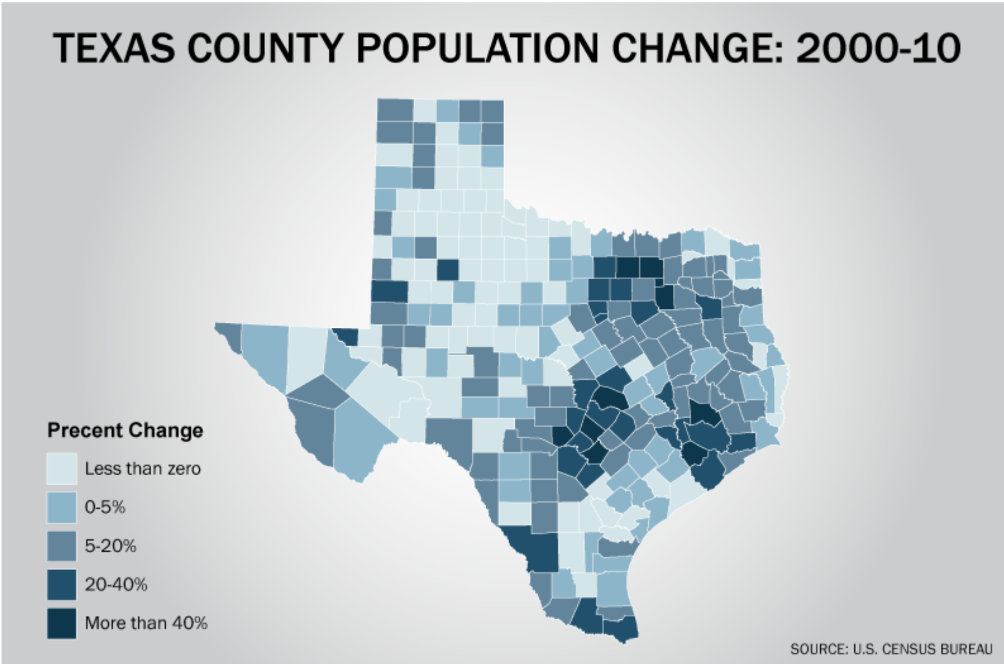

Figure 1-3. Texas population growth from 2000-2010. Figure from Texas Tribune based on U.S. Census data. http://www.texastribune.org/library/data/census-2010/.

Table 1-1. 10 fastest growing cities in Texas[4]2010-2014.

City	2010 Population	2014 Population	Percent Change
San Marcos	44,894	58,892	31.18%
Cedar Park	48,937	63,574	29.91%
Georgetown	47,400	59,102	24.69%
Frisco	116,989	145,035	23.97%
McKinney	131,117	156,767	19.56%
Conroe	56,207	65,871	17.19%
Pflugerville	46,936	54,644	16.42%
Austin	790,390	912,791	15.49%
Midland	111,147	128,037	15.20%
New Braunfels	57,740	66,394	14.99%

[4] http://www.texastribune.org/2015/05/21/interactive-texas-population-growth-2010-2014/

2.0 CONCEPTUAL MODEL OF OZONE FORMATION IN THE HOTCOG AREA

The purpose of the conceptual model is to provide a basis of understanding of ozone in the Waco region and to provide a foundation for all ozone air quality planning activities. EPA's *Draft Modeling Guidance for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze*[5] indicates that the first activity to be completed in ozone air quality planning is the formulation of a conceptual model that qualitatively describes ozone formation mechanisms and provides a rationale for selection of episodes for photochemical modeling. EPA's Modeling Guidance specifies that the key components of the conceptual model are analyses of air quality, meteorological and emissions data. Through these analyses, relationships between weather conditions and high ozone events may be established, important emissions sources and trends may be identified, and periods of high ozone suitable for modeling may be selected. Ozone modeling may be used to shed light on the causes of high ozone events as well as the likely effectiveness of proposed control strategies. Section 2 summarizes the conceptual model of ozone formation in the HOTCOG area (McGaughey et al., 2010a; 2012; Parker et al., 2013) and describes results of recent analyses of air quality, emissions and meteorological data and trends.

2.1 Attainment Status and Recent Ozone Trends

The location of the TCEQ's Waco Mazanec ozone monitor (CAMS 1037) is shown in Figure 2-1. The Waco Mazanec monitor is located northeast of the Waco metropolitan area in McLennan County. At the Waco site, the following measurements are made on a routine basis: meteorological data (winds, temperature, etc.), ozone, oxides of nitrogen, carbon monoxide, sulfur dioxide, and fine particulates ($PM_{2.5}$). These quantities are reported to the TCEQ's automated reporting system on an hourly basis. The Waco Mazanec site began operating in April, 2007, and has always monitored attainment of the NAAQS.

The upper panel of Figure 2-2 shows recent trends in 4th highest daily maximum 8-hour average ozone values (MDA8) and 8-hour ozone design values at the Waco Mazanec monitor. Since the Waco monitor began operating in 2007, its 4th high MDA8 value has varied between a low of 63 ppb and a high of 78 ppb. Between 2007 and 2012, the 4th high value alternated between increases and decreases, showing a weakly positive trend (0.3 ppb year^{-1}). The 4th high value in 2014 was the lowest recorded and 2015 also had a relatively low value. Because of the recent low values of the 4th high MDA8 ozone, the overall trend from 2007-2015 is downward (-0.62 ppb yr^{-1}).

The Waco Mazanec monitor's design value ranged between 70-72 ppb until the 2011-2013 period, when the design value rose to 74 ppb (lower panel of Figure 2-2). Overall, the design value shows a decreasing trend from 2007-2015 (-0.54 ppb yr^{-1}). However, the new, more stringent 2015 NAAQS of 70 ppb means that despite the improvement in ozone air quality

[5] http://www3.epa.gov/scram001/guidance/guide/Draft_O3-PM-RH_Modeling_Guidance-2014.pdf

shown in Figure 2-2, the Waco monitor's current design value is within 3 ppb of the NAAQS. Therefore, air quality planning remains important for the HOTCOG area.

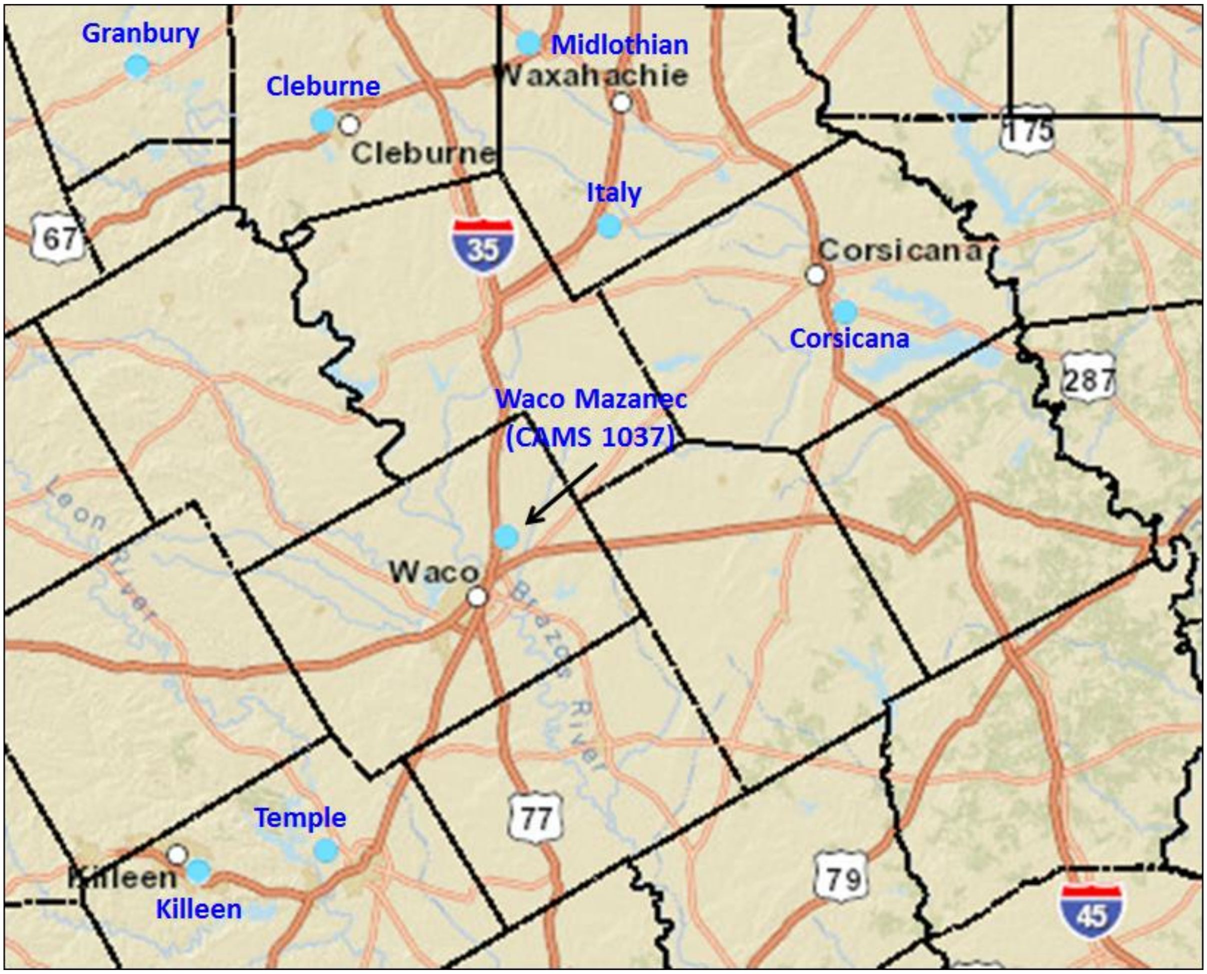

Figure 2-1. Waco Mazanec CAMS monitor location. Adaptation of TCEQ figure from http://gis3.tceq.state.tx.us/geotam/index.html, accessed December 15, 2013. Blue circles indicate the locations of ozone monitors.

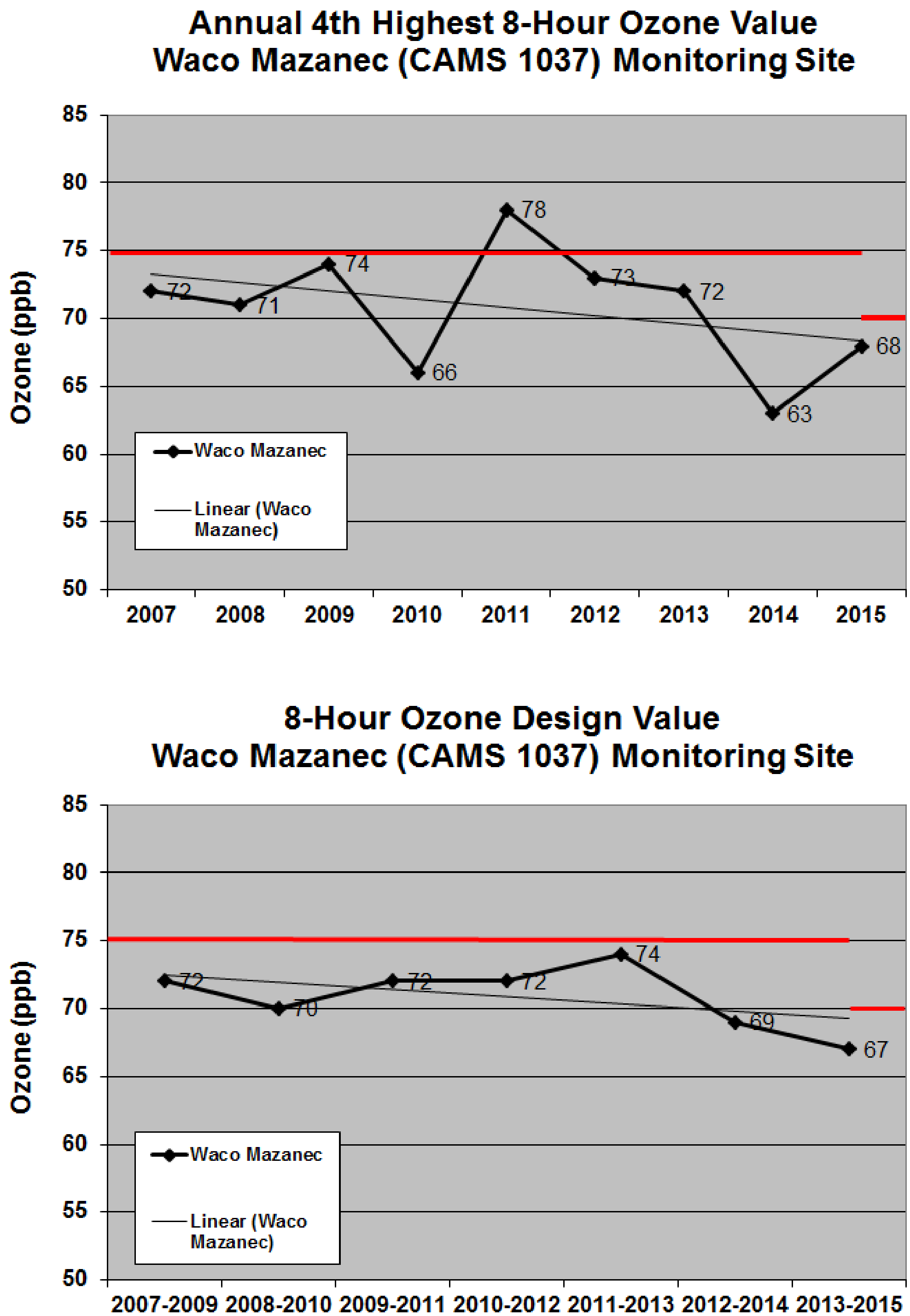

Figure 2-2. Trends in annual 4th highest daily maximum 8-hour ozone values (upper panel) and design values (lower panel) at the Waco Mazanec monitors in McLennan County. The dashed red line indicates the 2008 75 ppb ozone standard and the 2015 70 ppb ozone standard. All data have been validated by the TCEQ.

Figure 2-3 shows the number of days with MDA8>70 ppb at the Waco monitor for each year from 2007-2015. We define a high ozone day to be a day on which the MDA8 exceeded 70 ppb at the Waco Mazanec (CAMS 1037) monitor. 2011 had the largest number of high ozone days as well as the highest value of the 4th high MDA8 (Figure 2-2). The hottest summer ever recorded in Texas occurred in 2011[6] and hot weather is conducive to ozone formation. In 2011, Texas was also affected by numerous wildfires, and wildfire emissions can contributed to high ozone.

The seasonal variation of high ozone days at the Waco monitor is shown in Figure 2-4. The Waco monitor had the largest number of high ozone days during the August-September period during the years 2007-2015 with 14 days with MDA8>70 ppb in each month. The monitor had six high ozone days in June and October, and a smaller number in May (five) and July (four). There were no days with MDA8>70 ppb during the months of January-April and November-December at the Waco (CAMS 1037) monitor.

The number of high ozone days by day of week for the Waco Mazanec (CAMS 1037) monitor is shown in Figure 2-5 and Figure 2-6. Figure 2-5 shows the raw count of number of high ozone days for each day of week at the monitor, and Figure 2-6 shows the number of high ozone days by weekend day versus weekday. In Figure 2-6, the number of days in each category is normalized to give equal weight to weekend and weekday days. The total number of weekdays at each monitor is divided by five and the total number of weekend days is divided by two. Figure 2-5 and Figure 2-6 indicate that the Waco monitor has more high ozone days on weekdays than on weekends. This suggests the importance of vehicle emissions in contributing to local ozone, since vehicle activity is generally reaches its peak values during weekday commuting hours.

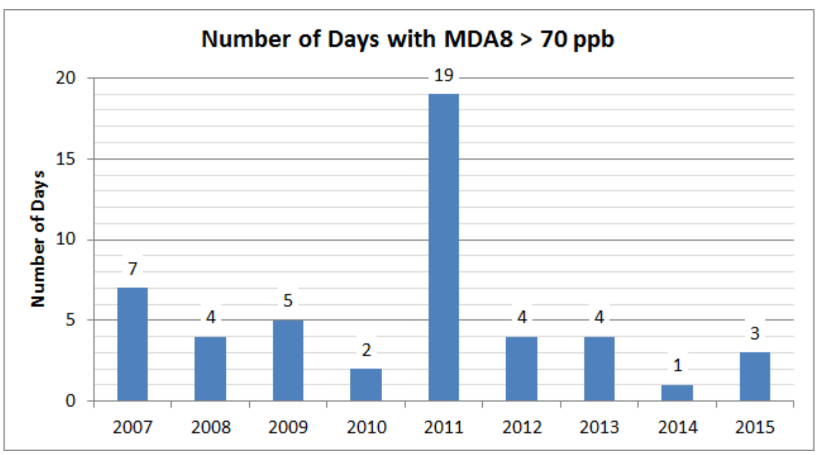

Figure 2-3. Number of days with MDA8>70 ppb at the Waco (CAMS 1037) monitor during 2007-2015.

[6] http://www.ncdc.noaa.gov/sotc/national/2011/8

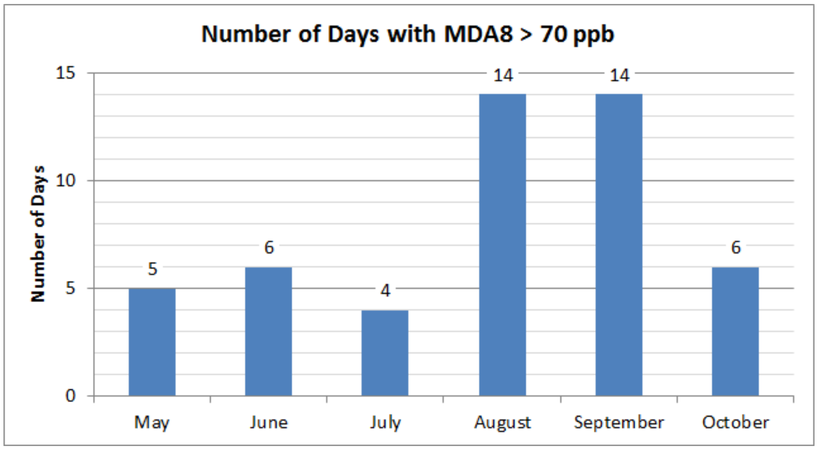

Figure 2-4. Number of days during each month with MDA8>70 ppb at the Waco (CAMS 1037) monitor during the period 2007-2015.

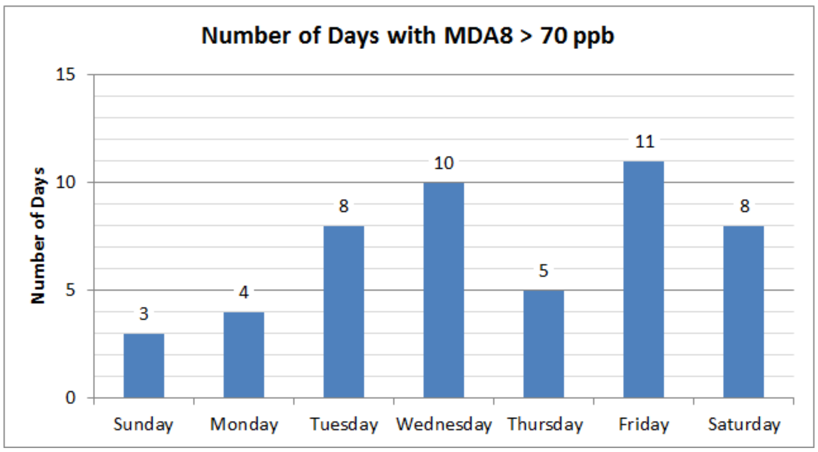

Figure 2-5. Number of days with MDA8>70 ppb by day of week at the Waco (CAMS 1037) monitor during the period 2007-2015.

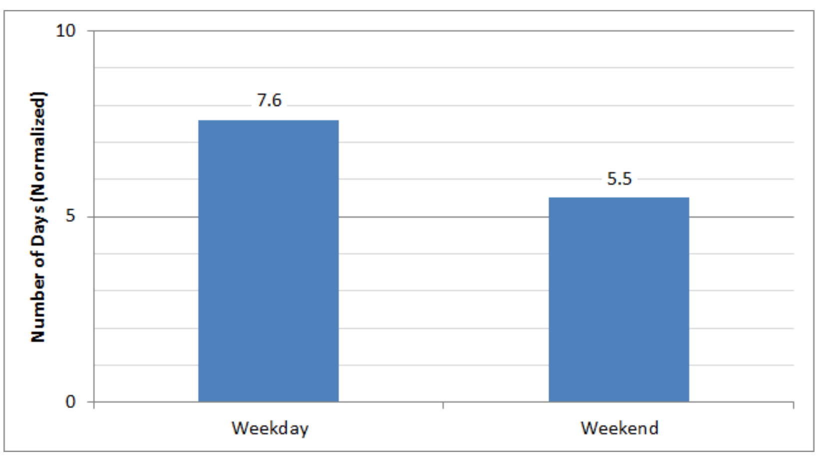

Figure 2-6. Number of high ozone days by day of week at the Waco (CAMS 1037) monitor during the period 2007-2015 normalized by number of days per week in each category.

2.2 Emissions

In this section, we review the emission inventory of ozone precursors for the HOTCOG area. As discussed in Section 1.1, ozone is not emitted directly, but is formed in the atmosphere from precursor emissions, mainly NOx and VOC. In Section 2.2, we provide an overview of the most recent HOTCOG area emission inventory, note recent emissions trends, and discuss the source categories that make the most important contributions to the HOTCOG area's NOx and VOC emission inventories.

At the time of writing, the most recent year for which HOTCOG area emissions inventories were available for both anthropogenic and biogenic emissions was 2012. The 2012 emission inventories were developed by the TCEQ for use in photochemical modeling by the Texas Near-Nonattainment Areas, and are broken down by emissions source category. The inventories were downloaded from the TCEQ's Rider 7/8 ozone modeling website at http://www.tceq.texas.gov/airquality/airmod/rider8/rider8Modeling. We also analyzed 2006 emissions prepared by the TCEQ for some anthropogenic emission source categories in order to identify 2006-2012 emissions trends in the 6-county area. First, we examine HOTCOG area-wide emissions and trends. Then, we review the emissions and trends in individual emissions source categories. Finally, we analyze the entire emission inventory to determine whether NOx or VOC is the limiting factor in ozone formation in the HOTCOG area. A detailed emissions analysis for the 2012 inventory is currently being performed by HOTCOG and will be presented in a forthcoming document, Grant et al., (2016), and summarized in the 2017 update to the Ozone Advance Action Plan.

2.2.1 Emissions Summary

Figure 2-7 and Figure 2-8 show 2012 and 2006 ozone season day NOx and VOC emissions by source category in the HOTCOG area. Figure 2-7 shows both anthropogenic and biogenic emissions source categories, and illustrates the fraction of the total inventory comprised by each source category. Figure 2-8 shows the same anthropogenic emission inventory data as Figure 2-7, but allows easier visualization of the changes in magnitude of anthropogenic emissions between 2006 and 2012. Figure 2-9 shows the distribution of HOTCOG area 2012 anthropogenic NOx and VOC emissions by county and source category.

Total NOx emissions for the HOTCOG area decreased from 185 tpd in 2006 to 140 tpd in 2012, and total VOC emissions decreased from 1,390 tpd in 2006 to 693 tpd in 2012. Figure 2-8 shows that there were decreases in all categories of anthropogenic NOx emissions going from 2006 to 2012. For VOC, there were decreases in all categories of anthropogenic emissions going from 2006 to 2012 except point sources, which had an increase of 0.3 tpd. Most of the decrease in VOC emissions is due to a reduction in biogenic emissions, which are discussed in Section 2.2.5. Anthropogenic area source VOC emissions also saw a decline from 64 tpd in 2006 to 39 tpd in 2012. The relative contribution of the different NOx and VOC emissions source categories is similar in 2006 and 2012 (Figure 2-7).

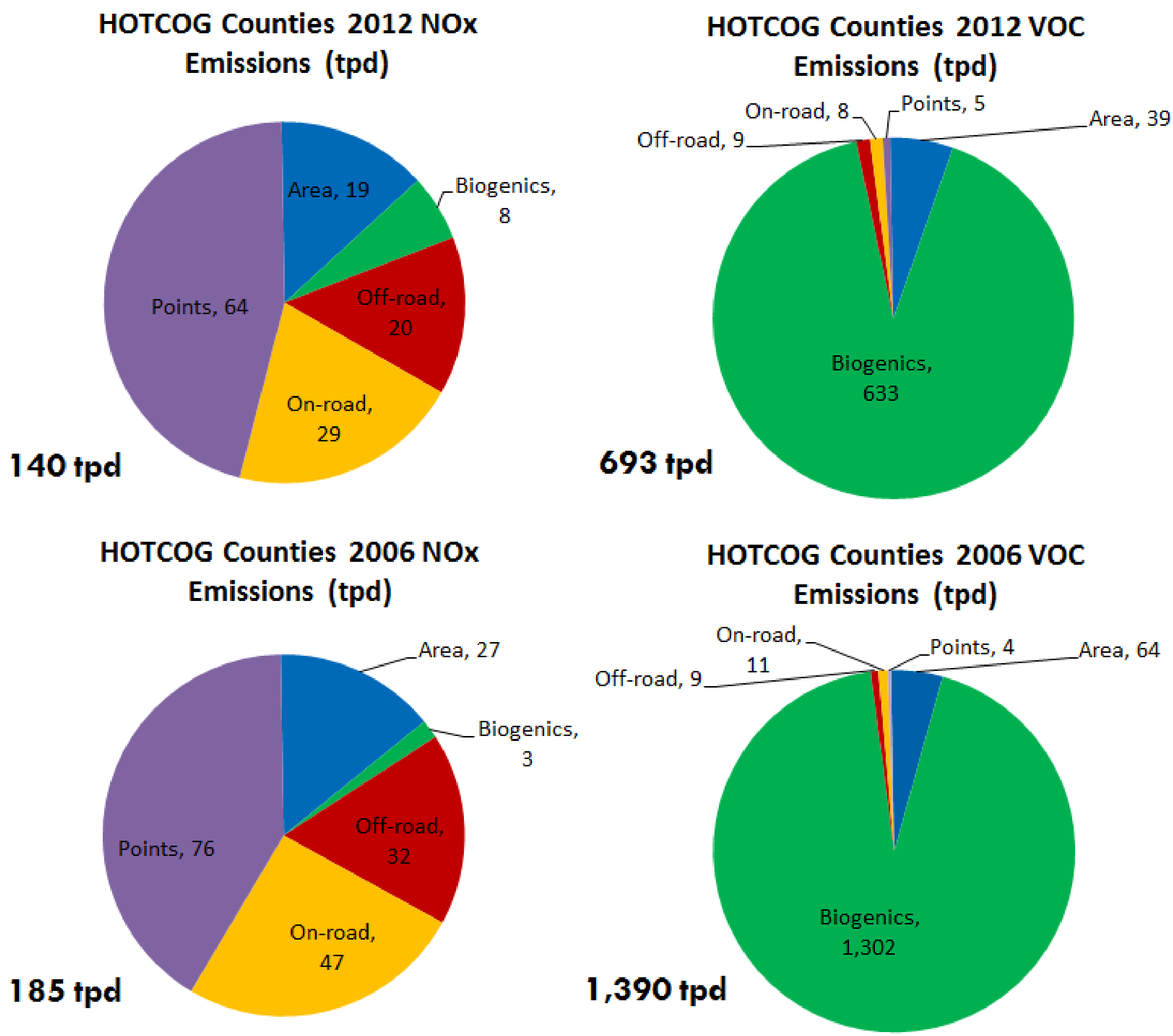

Figure 2-7. Emissions summaries for 2006 and 2012.

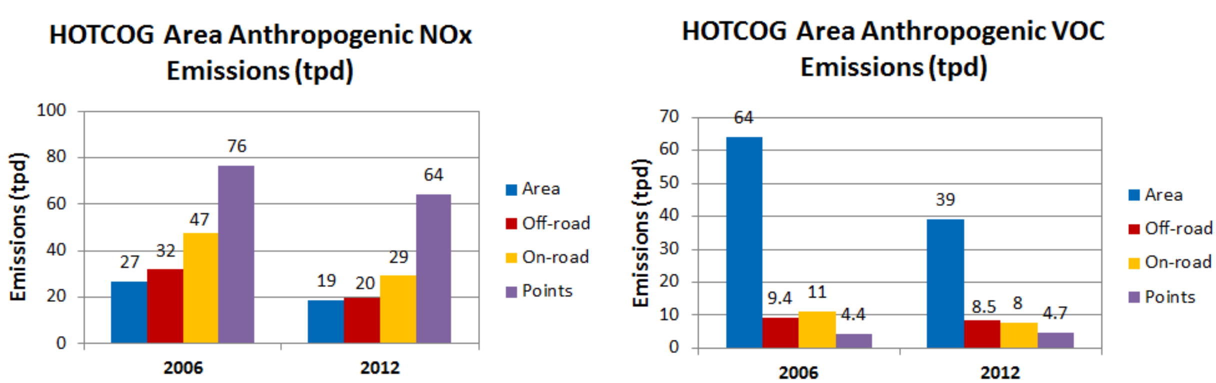

Figure 2-8. 2012 HOTCOG 6-county area anthropogenic NOx emissions (left panel) and VOC emissions (right panel).

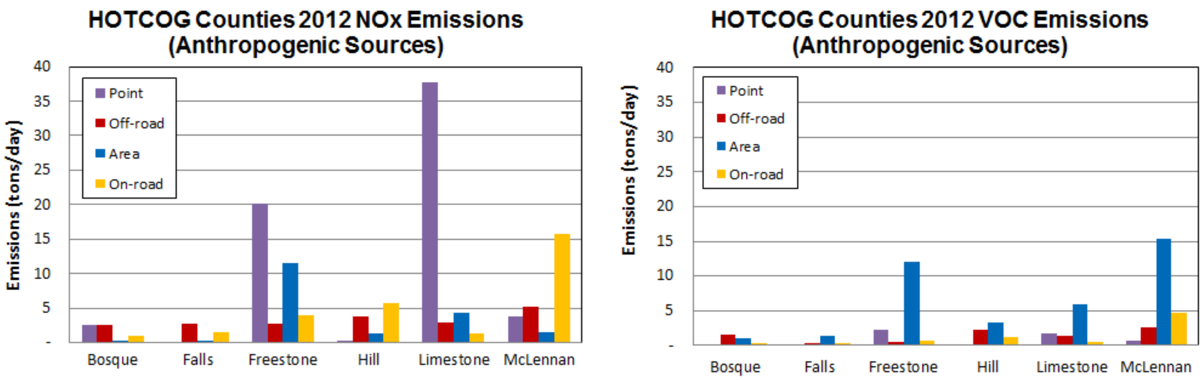

Figure 2-9. 2012 HOTCOG anthropogenic NOx (left panel) and VOC (right panel) emissions by county.

2.2.2 On-Road Mobile Emissions

On-road mobile emissions are the second largest contributor to the 2012 HOTCOG area NOx emission inventory (29 tpd). On-road emission estimates were developed by the TCEQ using the EPA's Motor Vehicle Emissions Simulator (MOVES) emission model[7]. The emissions totals represent the sum of HOTCOG county-wide emissions for a summer weekday. On-road NOx decreased from 47 tpd in 2006 to 29 tpd in 2012. Traffic counts collected along the two major interstate highways in the HOTCOG area show an increase in I-35 traffic counts and little change in I-45 traffic counts between 2002 and 2012[8]. Local population in the HOTCOG area has increased between 2006 and 2012. Therefore, the reduction in on-road mobile source emissions is due to turnover of the vehicle fleet to newer and cleaner equipment. McLennan County has higher on-road NOx and VOC emissions than the other HOTCOG counties. This is due to the larger population of McLennan County compared to the other counties (Figure 1-2) taken together with the presence of the heavily-travelled Interstate I-35 Highway in McLennan.

2.2.3 Off-Road Mobile Emissions

Off-road mobile source emissions are from mobile and portable internal combustion-powered equipment not generally licensed or certified for highway use. Off-road emissions equipment categories span a wide range of equipment types such as lawn and garden equipment, heavy-duty construction equipment, aircraft and locomotives. Off-road emissions for many of these categories are calculated using EPA's NONROAD emission model[9]. TCEQ has developed a Texas-specific application of the NONROAD model called TexN (ERG, 2014) for counties within Texas. HOTCOG area NOx emissions from off-road mobile sources totaled 32 tpd in 2006 and 20 tpd in 2012. The reduction in offroad NOx emissions between 2006 and 2012 is largely due to reductions in emissions from agricultural equipment and well drilling (Grant et al., 2016). McLennan County has the highest 2012 off-road emissions of all HOTCOG counties; all six of the counties have roughly comparable contributions from agricultural, construction and mining

[7] http://www3.epa.gov/otaq/models/moves/
[8] Google Earth Pro traffic count data attributed to KSS Fuels, http://www.kssfuels.com/Solutions/Data_Intelligence/TrafficMetrix%20_Published_Counts.html
[9] http://www.epa.gov/otaq/nonrdmdl.htm

equipment, but McLennan has higher emissions from locomotives and industrial sources than the other counties (Grant et al., 2016).

2.2.4 Area Source Emissions

The area source inventory treats in aggregate all stationary sources that have emissions below the point source threshold. These are sources that may be spread out geographically and are small individually, but taken together may constitute a sizeable amount of emissions. Examples of area sources include dry cleaners, residential wood heating, auto body painting, fires, oil and gas wells and consumer solvent use. These emissions are typically estimated and reported as county totals and allocated to a finer geographic scale using a surrogate such as population density. For example, if a certain amount of VOC emissions are allocated to dry cleaners in a given county most of those emissions would be allocated to the locations within the county that have the highest population density.

Figure 2-10 shows the breakdown of 2012 area source NOx and VOC emissions for each HOTCOG county into contributions from oil and gas sources and all other emissions sources. Area source NOx emissions are largest in Limestone and Freestone Counties followed by McLennan and Hill Counties. NOx emissions from oil and gas sources dominate the area source emission inventory in Limestone and Freestone. NOx emissions from the oil and gas source category come primarily from natural gas production equipment. The 2014 distribution of oil and gas wells in the HOTCOG area is shown in Figure 2-12 and indicates that there are far more gas wells than oil wells in the HOTCOG area. HOTCOG area natural gas wells are concentrated in Limestone and Freestone Counties, with a lesser number in Hill County, which marks the southernmost extent of the Barnett Shale formation.

VOC emissions are emitted from equipment at both oil and gas wells. For Limestone and Freestone Counties, the area source VOC emission inventory is composed mainly of oil and gas emissions (Figure 2-10). McLennan County, on the other hand, has few wells, and its area source emissions are nearly all from non-oil and gas sources. McLennan County has the largest population of all HOTCOG Counties, so that all area sources whose calculations are indexed to population have their highest values in McLennan.

The oil and gas NOx emission inventory is dominated by a single source category. Figure 2-11 shows that gas compressor engines constitute 99% of the 2012 HOTCOG oil and gas NOx emission inventory, with the remaining 1% coming from artificial lift engines used for oil production. Gas compressor engines are used to extract natural gas from a well when reservoir pressures alone are insufficient to bring the gas to the surface. Compressor engines are also used to transmit natural gas along pipelines from the well to gas processing plants and then to consumers. In a mature gas field, such as those found in Freestone and Limestone Counties, the need for compression to produce the gas increases over time as the subsurface gas reservoir is drained and reservoir pressures drop. In Freestone and Limestone Counties, gas compressor engines are the largest component of the oil and gas NOx emission inventory.

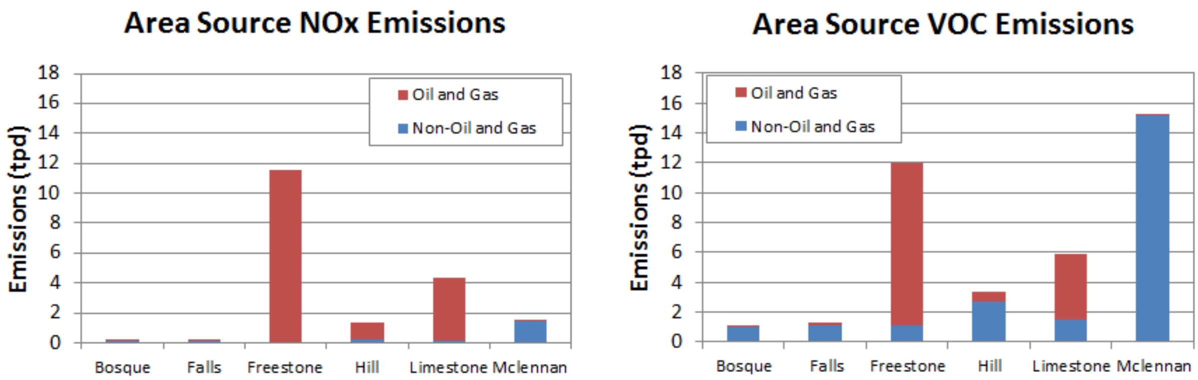

Figure 2-10. Contribution of oil and gas emissions to 2012 HOTCOG total area source emissions.

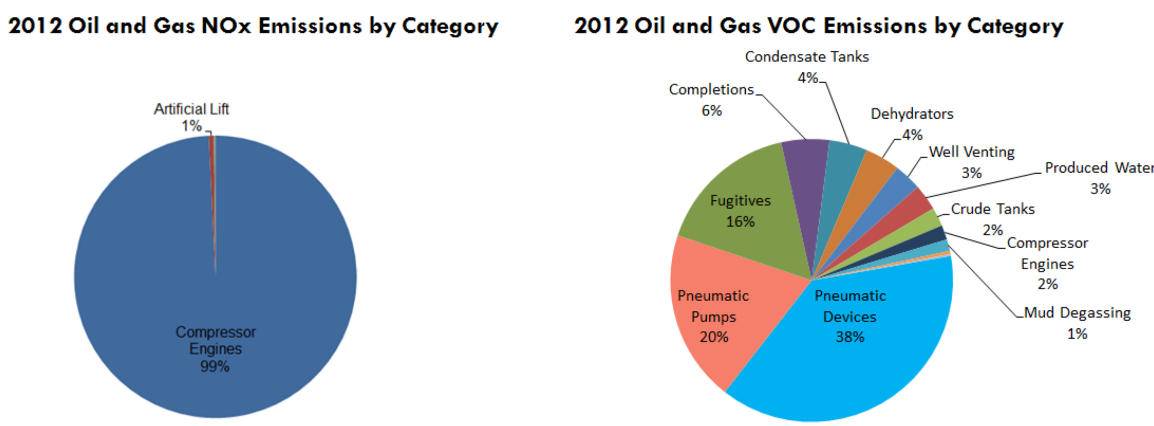

Figure 2-11. 2012 HOTCOG area oil and gas NOx (left panel) and VOC (right panel) emissions source category breakdown.

The number of compressor engines in the HOTCOG counties and their horsepower and level of NOx emission control is not well characterized.

In March, 2010, a Texas emissions reduction measure known as the East Texas Combustion Rule went into effect. The East Texas Combustion Rule requires owners and operators of stationary, rich-burn gas-fired, reciprocating internal combustion engines greater than or equal to 240 HP in 33 East Texas counties (including Limestone and Freestone Counties) to meet NOx emission limits and follow specified reporting requirements. The fraction of gas compressor engines in the 6-county area that have horsepower < 240 HP and are therefore not required to comply with the East Texas Combustion Rule is not known. The TCEQ emission inventory calculations for gas compressor engines assume 100% compliance with the East Texas Combustion Rule.

Gas compressor engines represent a source of significant uncertainty in the HOTCOG NOx emission inventory.

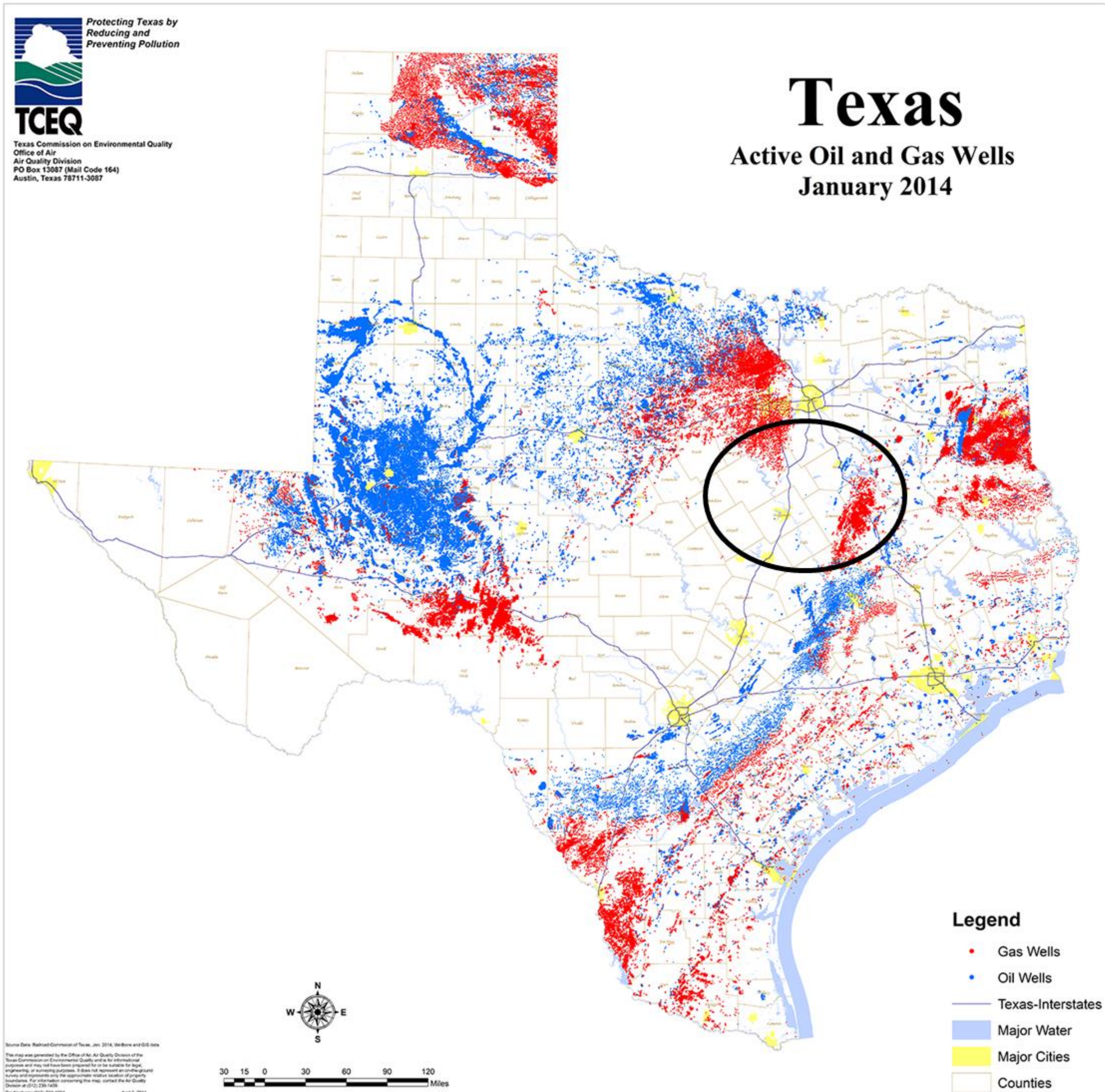

Figure 2-12. Texas oil and gas well locations as of January 2014. TCEQ figure from http://www.tceq.state.tx.us/assets/public/implementation/barnett_shale/bs_images/txOilGasWells.png. Black circle indicates the location of the HOTCOG 6-county area.

The HOTCOG 2012 VOC emission inventory for oil and gas sources is distributed across a larger number of source cateogries than the NOx inventory (Figure 2-11). Pneumatic devices, pneumatic pumps, and fugituve emissions make the largest contributions.

In 2006, HOTCOG area NOx emissions from oil and gas sources totaled 24 tpd, while VOC emissions were 35 tpd. In 2012, HOTCOG area oil and gas NOx and VOC emissions had declined to 17 tpd and 16 tpd, respectively. Figure 2-13 shows recent trends in HOTCOG area oil and gas well counts. Figure 2-14 show trends in HOTCOG area-wide production of natural gas and liquid hydrocarbons (the sum of crude oil and condensate production).

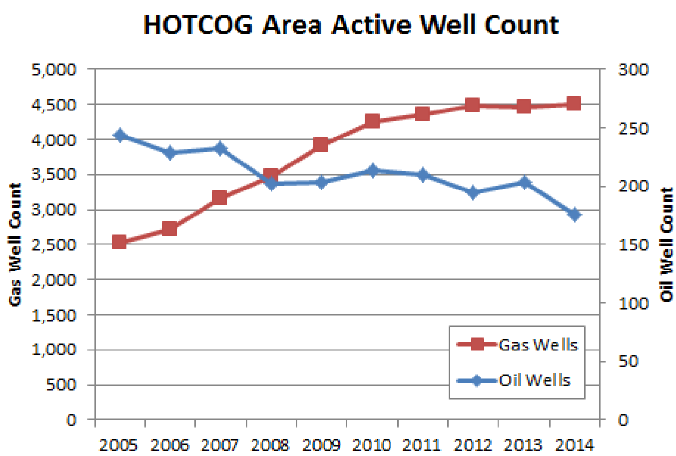

Figure 2-13. HOTCOG area oil and gas well count trends.

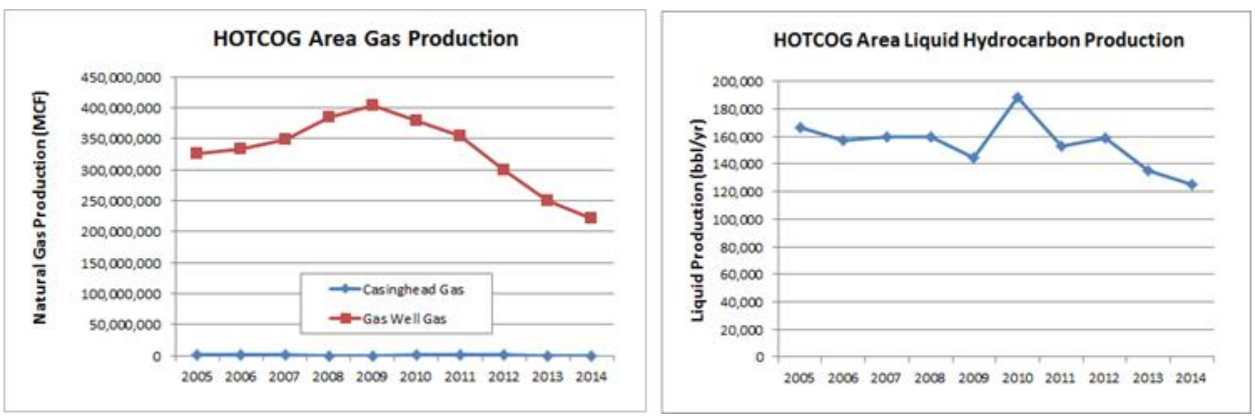

Figure 2-14. HOTCOG area natural gas (left panel) and liquid hydrocarbon (sum of oil and condensate production) production trends.

Figure 2-13 shows that the number of oil wells decreased between 2006 and 2012, and in both years, is very small compared to the number of gas wells. From 2005 to 2012, the number of gas wells in the HOTCOG area increased, but the well count leveled off after 2012. Drilling slowed in 2010 due to low natural gas prices and a glut of natural gas from shale formations around the U.S. Gas production increased from 2005 to 2009 due to the drilling of new wells in the HOTCOG area, but after 2009, gas production began to decline as the pace of drilling slackened. Note that gas production was higher in 2006 than in 2012. Emissions calculations for the largest components of the oil and gas NOx and VOC inventories (gas compressor engines, pneumatic devices and pneumatic pumps) scale with gas production. Therefore, the 2006 to

2012 decrease in emissions from natural gas sources is consistent with declines in natural gas production. Changes in oil and gas emissions from 2006 to 2012 may also be due to improvements in TCEQ's oil and gas area source emissions estimation methodology (effect varies depending on source category) as described in Grant et al. (2015; 2016).

2.2.5 Biogenic Emissions

Biogenic emissions sources are naturally-occurring (i.e., not from human activities) and are emitted by vegetation such as trees and agricultural crops as well as by microbial activity in soils or water. Some biogenic VOC such as isoprene and pinenes are highly reactive, which means they are especially likely to contribute to ozone formation. The 2012 biogenic emission inventory was developed by the TCEQ using the Model of Emissions of Gases and Aerosols from Nature (MEGAN; Guenther et al., 2012) version 2.10. MEGAN calculates hourly, day-specific emissions that depend on photosynthetically active solar radiation and temperature as well as other inputs such as land cover. Episode average biogenic emissions were extracted from the TCEQ biogenic emission inventory for the 6-county area for the period June 1-30, 2012. Episode average biogenic emissions totals by county were derived from the data for each county in the HOTCOG area. Each model grid cell was assigned to a county using GIS tools.

Biogenic emissions are the largest contributor to the VOC emission inventory in both 2006 and 2012, accounting for 633 tpd (91%) of the total VOC emissions in 2012 (Figure 2-7). The large reduction in biogenic VOC emissions going from 2006 to 2012 may be due to use of different versions of the MEGAN model and its inputs as well as differences in weather between June 2006 and June 2012. Figure 2-7 shows that VOC emissions in the HOTCOG area are dominated by biogenic emissions; anthropogenic sources account for a much smaller fraction of total daily VOC emissions.

HOTCOG area VOC emissions are primarily from biogenic sources, constituting 79% of the total in McLennan County and a higher proportion in the other, more rural counties. Figure 2-15 shows ozone season day total anthropogenic and biogenic VOC emissions for the 6-county HOTCOG Area. For all counties, the contribution to the VOC inventory from biogenic emissions far exceeds that of the anthropogenic emissions. Total anthropogenic emissions of VOC from Freestone County are similar to McLennan County, but they are primarily from the oil and gas sector rather than distributed across a broad range of sectors, as is the case for McLennan.

NOx emissions from biogenics (8 tpd in 2012) are relatively small compared to NOx emissions from the anthropogenic emissions categories (Figure 2-7).

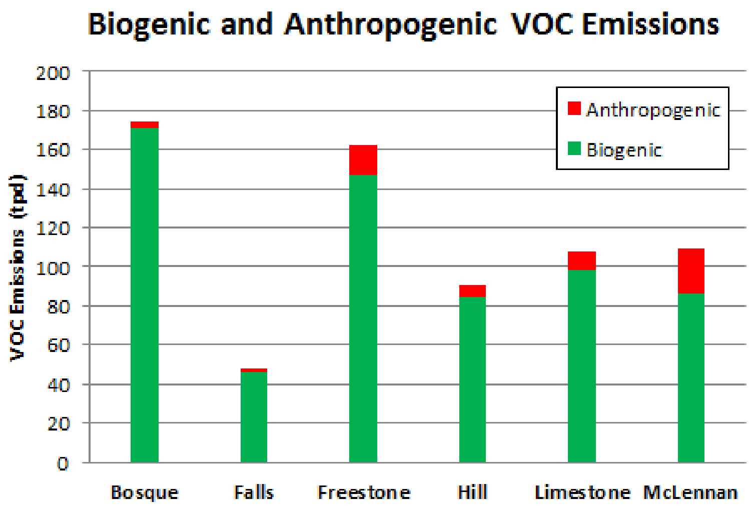

Figure 2-15. 2012 ozone season day total anthropogenic and biogenic VOC emissions by county.

2.2.6 Point Source Emissions

In this section, we summarize the point source emission inventory for the HOTCOG area. Point sources are stationary emission sources that exceed a specified emissions threshold. Point source emissions are frequently, but not always, released through a stack. In non-attainment areas of Texas, the TCEQ defines a point source to be any industrial, commercial, or institutional sources that emits actual levels of criteria pollutants at or above the following amounts: 10 tons per year (tpy) of VOC; 25 tpy of NOx; or 100 tpy of any of the other criteria pollutants including CO, SO_2, PM_{10}, or lead. In attainment areas of the state, any company that emits a minimum of 100 tpy of any criteria pollutant must submit a point source emissions inventory to the TCEQ. Each point source has a well-defined location (latitude and longitude) as well as ancillary information known as stack parameters that indicate the height at which emissions are released, the temperature of emitted gases, etc.

The TCEQ's 2012 point source emission inventory for the HOTCOG area was compiled from data from the TCEQ's State of Texas Air Reporting System (STARS) and the EPA's Acid Rain Program Database (ARPDB). The STARS database is administered by the TCEQ. Each year, the TCEQ sends questionnaires to all facilities that meet the reporting requirements of 30 Texas Administrative Code (TAC) §101.10. The TCEQ collects point source emissions data as well as industrial process operating data. For all sources except electric generating units (EGUs), the TCEQ uses this data to compile Ozone Season Day (OSD) emissions. The OSD emission rate represents average daily emissions during the summer, when ambient ozone in Texas tends to be highest.

Point sources were the largest emissions source category in the HOTCOG NOx emission inventory in both 2006 and 2012, accounting for 64 tpd (46%) of the total NOx emissions in 2012. Point source NOx emissions decreased from 76 tpd in 2006 to 64 tpd in 2012. Figure 2-9 shows that 2012 point source NOx emissions are concentrated in Limestone and Freestone Counties, home to two power plants which comprise the bulk of the inventory.

Figure 2-16 shows the location of all point sources with 2012 NOx emissions ≥ 0.1 tpd in the HOTCOG 6-county area. The Waco monitor has a number of small (1 – 3 tpd) NOx-emitting point sources within 13 miles to its south and east. The two largest 2012 HOTCOG area NOx point source emitters (Limestone, 37 tpd; Big Brown, 16 tpd) are both within 65 miles to the east/southeast of the Waco Mazanec (CAMS 1037) monitor. Under typical wind directions on high ozone days (northerly through easterly to southerly,) the Limestone or Big Brown power plants can lie upwind of the monitor, but analysis performed by McGaughey et al. (2010a; 2012) and Parker et al. (2013) indicates that high ozone at the Waco monitor frequently occurs without the presence of SO_2 that is indicative of a coal-fired power plant plume impact. Therefore, Limestone and Big Brown have the potential to influence ozone at the Waco Mazanec (CAMS 1037) monitor, but this does not appear to have occurred frequently on high ozone days through 2013. HOTCOG is currently analyzing high ozone days through the 2015 ozone season and will assess whether coal-fired power plant emissions contributed to high ozone at the Waco Mazanec monitor during the 2014-2015 ozone seasons. The results of this analysis will be reported in the 2017 update to the Ozone Advance Action Plan.

Emissions from point sources are a relatively small fraction of the total HOTCOG VOC emission inventory in both 2006 and 2012. The HOTCOG area VOC emission inventory is comprised of a number of small sources rather than being dominated by a small number of large sources as is the NOx emission inventory; instead, many point sources have low and roughly comparable VOC emission rates. Figure 2-7 indicates that anthropogenic point VOC emissions are small compared to other VOC emission source categories in 2006 and 2012. In particular, biogenic VOC emissions dominate the inventory, and so the location of the point VOC emissions is unlikely to play a significant role in ozone levels at the Waco monitor. Therefore, we do not show a VOC point source plot comparable to Figure 2-16.

2.2.6.1 Point Source Emissions from Power Plants

The HOTCOG point source NOx emission inventory is dominated by emissions from power plant electric generating units (EGUs). In 2012, HOTCOG point source NOx emissions totaled 64 tpd, of which 56 tpd (88%) were from power plants. The EPA requires all utility units serving generators with an output capacity of greater than 25 megawatts and all new utility units to continuously measure and record their emissions of SO_2, NOx, and CO_2, as well as other quantities such as heat input. This is accomplished through in-stack monitoring using a Continuous Emissions Monitor (CEM). All sources must submit hourly emissions data to the EPA's Clean Air Markets Division (CAMD) Acid Rain Program Database (ARPDB) on a quarterly basis. For each Texas EGU, the TCEQ downloaded the hourly CEM data from the ARPDB and used this hourly data in their emissions modeling. Because VOC and CO emissions are not reported in the ARPDB, the TCEQ calculates hourly emissions for these pollutants by multiplying the STARS OSD VOC-to-NOx and CO-to-NOx emissions ratios by the hourly ARPDB NOx emissions (TCEQ, 2010).

Although the hourly EGU emissions are used in ozone modeling to provide the most accurate possible simulation of the emission, transport and fate of EGU emissions, OSD average emissions were generated for EGUs from the hourly data for the emissions analysis presented here. For EGU sources in the HOTCOG area, hourly 2012 CEM emissions data were extracted by the TCEQ. The TCEQ then developed baseline emissions for EGUs[10]. Baseline emissions are typical emissions that represent a generic day of hourly averages based on the 4-month period of June 2012 through September 2012.

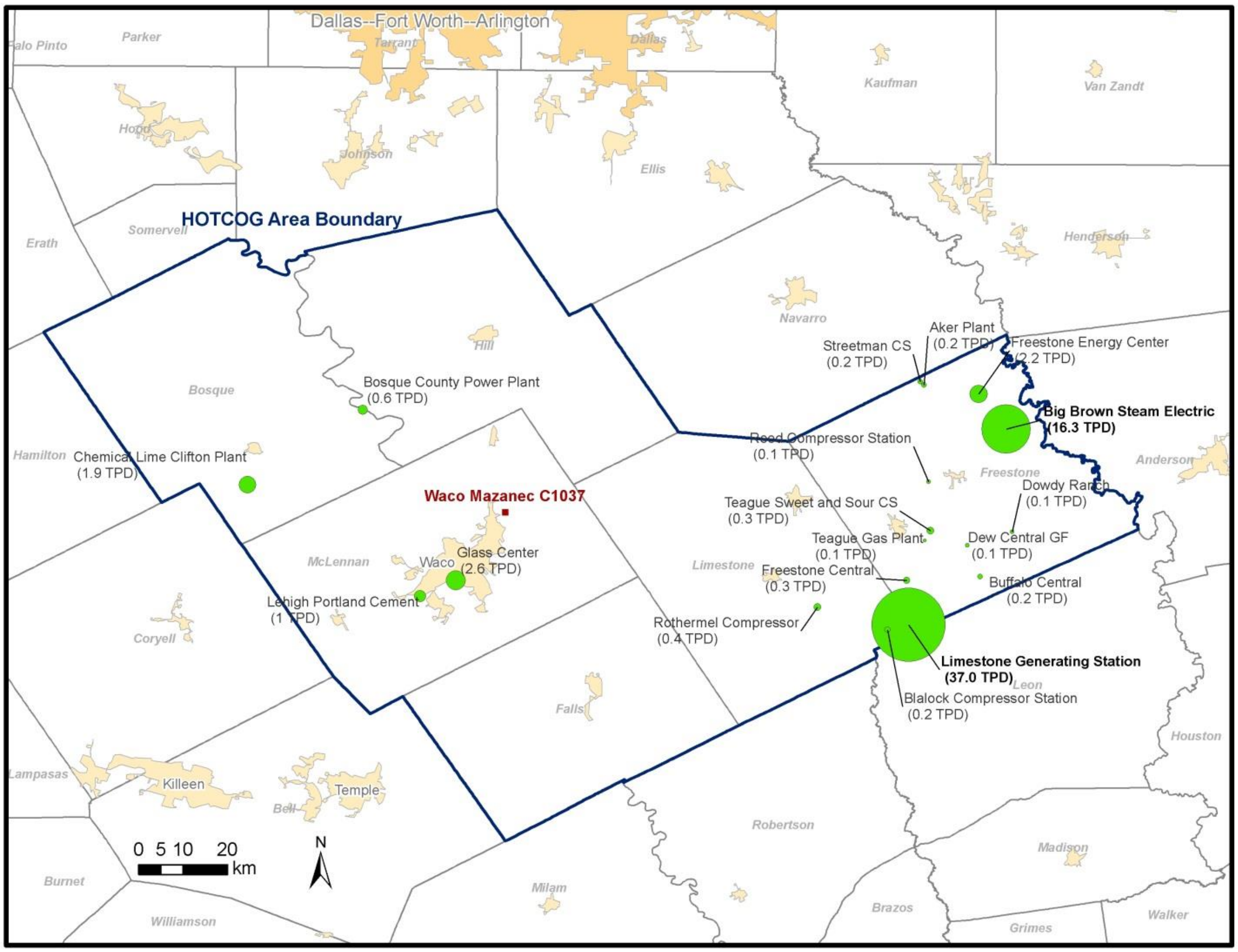

Figure 2-16. 2012 NOx emissions from point sources in the 6-County HOTCOG area for sources with NOx emissions ≥ 0.1 tpd. Area of circle is proportional to the NOx emissions rate.

For non-EGU sources (i.e. all other sources that are not power plant stacks) TCEQ's OSD average emissions estimates for HOTCOG 6-county area point sources were used directly. There were four facilities reporting emissions to the EPA ARPDB within the HOTCOG counties in 2012 and their ozone season daily emissions are presented in Table 2-1; the location of these facilities is shown in Figure 2-16. In Table 2-1, we include facility-wide power plant emissions for 2006 in

[10] ftp://amdaftp.tceq.texas.gov/pub/EI/2012/point/baseline/README

order to show trends in EGU facility emissions. The 2006 inventory power plant emissions were compiled by TCEQ using the same method as for 2012.

Table 2-1. 2006 and 2012 NOx emissions for power plants in the HOTCOG 6-county area.

Owner	Site	County	2006 [tpd]	2012 [tpd]
Bosque Power Co	Bosque County Power Plant	Bosque	0.90	0.60
Luminant Generation Co	Big Brown Power Plant	Freestone	20	16
Freestone Power Generation	Freestone Power Generation	Freestone	1.5	2.2
NRG Texas Power	Limestone Power Plant	Limestone	40	37
Luminant Generation Co	Lake Creek Power Plant	McLennan	1.1	--
Luminant Generation Co	Tradinghouse Power Plant	McLennan	3.1	--

The Sandy Creek Power Plant was not operational until 2013. Lake Creek and Tradinghouse were not operating in 2012.

Table 2-1 indicates that Big Brown (1,150 MW[11]) and Limestone (1,689 MW[12]) facilities together constitute most of the power plant NOx emissions for the 6-county HOTCOG area. These two coal-fired plants with total emissions of 53 tpd constitute 83% of the 64 tpd total NOx point source inventory for the 6-county area. Between 2006 and 2012, Big Brown and Limestone saw decreases in NOx emissions of 4 tpd and 3 tpd, respectively. Across the entire HOTCOG area, power plant NOx emissions decreased from 67 tpd in 2006 to 56 tpd in 2012.

The Sandy Creek Power Plant, a 925-megawatt coal-fired plant located in southern McLennan County (Figure 2-17), had not yet begun operating in June 2012, and is therefore not present in the TCEQ 2012 emission inventory. The Sandy Creek facility is located in a region that can be upwind of the Waco Mazanec ozone monitor on high ozone days (see Section 2.3). HOTCOG is currently analyzing emissions from this facility and will report on the emissions and their potential ozone impacts in the 2017 Ozone Advance Action Plan Update.

2.2.6.2 Proposed/Permitted EGUs at Tradinghouse and Lake Creek

Both the Tradinghouse Power Plant and the Lake Creek Steam Electric Station were included in the emission inventories for 2006, but were no longer in operation in 2012. New EGUs have been permitted and/or proposed at both the Tradinghouse and Lake Creek facilities by their operator, Luminant. In 2014, the TCEQ granted New Source Review (NSR) Permit 110357, which allows the Tradinghouse Power Company, LLC (Tradinghouse) to construct and operate two natural gas-fired, simple-cycle combustion turbine generating units (CTGs) at the Tradinghouse facility near Hallsburg in McLennan County (Figure 2-17). These simple cycle CTGs will have total generating capacity of 420-462 MW, depending on turbine model selection, and were permitted for peaking service as well as extended periods of operation or non-operation. The new CTGs will replace the two former EGUs at the Tradinghouse facility. These two lower

[11] http://www.luminant.com/wp-content/uploads/2015/02/BigBrown_Facts.pdf
[12] http://maps.nrg.com/media/attachments/PLA.2014_Limestone_v2.pdf

efficiency natural gas-fired electric generation boilers (565 MW Unit 1 and the 818 MW Unit 2) were removed from service in 2010 and were dismantled in 2014[13].

In 2015, Tradinghouse filed an amendment to Permit 110357 proposing to add a duct-fired heat recovery steam generator (HRSG) to each CTG as well as a common steam turbine generator (STG) and auxiliary equipment. This would add combined cycle capability to its already-permitted simple cycle CTG Units 1 and 2. Tradinghouse would retain the ability to operate Units 1 and 2 in simple cycle mode. Tradinghouse also proposed to add an additional set of CTGs, Units 3 and 4, as well as duct-fired HRSGs and a common STG so that Units 3 and 4 may also be used in either simple or combined cycle mode. The four new Tradinghouse CTG units together with the STG units would have a generating capacity of 1,140-1,274 MW.

In 2014, the TCEQ granted NSR Permit 117857, which allows the Lake Creek 3 Power Company LLC (Lake Creek) to construct and operate two natural gas-fired, simple-cycle CTGs at the Lake Creek facility near Riesel in McLennan County. The two simple cycle units will each provide ~230 MW for a total of ~460 MW, and were permitted for peaking service as well as extended periods of operation or non-operation. These two new CTGs will replace two lower efficiency natural gas-fired electric generation boilers (87 MW Unit 1 and the 230 MW Unit 2) that were retired in 2009 and dismantled in 2015[14].

The new EGUs are intended to respond to the expected increase in demand for power along the Interstate 35 corridor due to projected population growth[15]. The operation of the proposed EGUs at Sandy Creek, Tradinghouse and Lake Creek will result in new emissions of NOx, a precursor to ozone. NOx emissions from Tradinghouse and Lake Creek will be controlled through the use of dry low NOx combustors and Tradinghouse EGUs will further control NOx through ammonia injection/selective catalytic reduction when the units are operating in combined cycle mode.

[13] http://pov.energyfutureholdings.com/2014/06/tradinghouse-power-plant-implosion-gives-new-use-to-old-materials/
[14] https://www.energyfutureholdings.com/lake-creek-power-plant-unit-2-imploded/
[15] http://www.ercot.com/content/wcm/key_documents_lists/67261/2016_LTSA_Scenario_Development.pptx

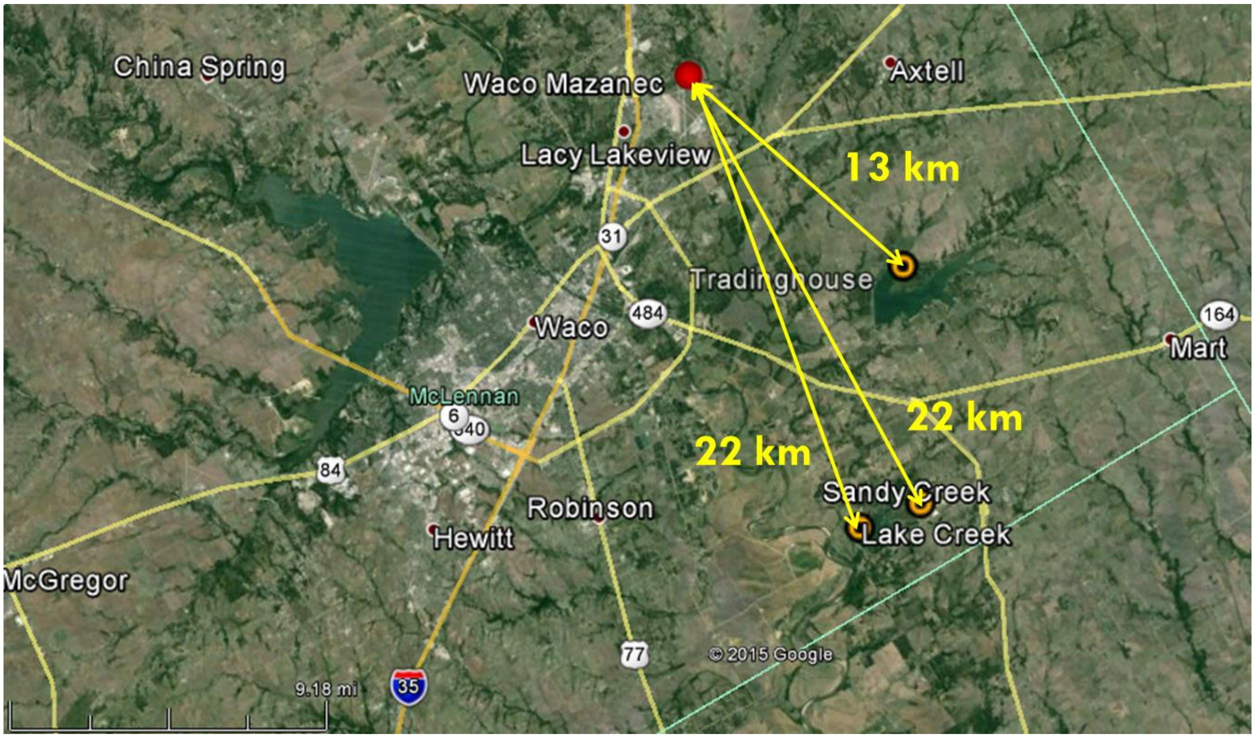

Figure 2-17. New and proposed EGUs in McLennan County. Filled orange circles with black dot in center show location of currently operating Sandy Creek facility and locations of permitted/proposed EGUs at the Tradinghouse and Lake Creek facilities. Yellow arrows indicate their respective distances from the Waco Mazanec (CAMS 1037) monitor, which is shown as a red filled circle.

Because the new EGUs would be located in a region that is often upwind of the Waco monitor on high ozone days (McGaughey et al., 2010; 2012; Parker et al., 2013), HOTCOG performed a photochemical modeling study to evaluate the potential ozone impacts of emissions from the newly permitted/proposed Tradinghouse and Lake Creek CTG units and ancillary facilities. HOTCOG's ozone model is described below, in Section 2.4, but the discussion of ozone modeling for newly permitted/proposed EGUs is presented here for continuity with the discussion of emissions. Ozone impacts were evaluated for a series of hypothetical utilization scenarios corresponding to the expected operating patterns for the new EGUs. Luminant provided emissions and operating profile data for their expected operating patterns, referred to below as the Realistic Emissions Scenario. NOx emissions for these Tradinghouse and Lake Creek scenarios are shown in Table 2-2.

Table 2-2. Summary of ozone season day facility-wide NOx emissions for Tradinghouse and Lake Creek for Luminant Realistic Emissions Scenarios. Simple cycle is abbreviated SC and combined cycle is abbreviated CC).

Facility and Operating Mode	NOx Emissions (tpd) Luminant Realistic Scenario
Lake Creek: 2 CTGs operating in simple cycle (SC) mode	0.75
Tradinghouse: 4 CTGs operating in simple cycle (SC) mode	1.49
Tradinghouse: 4 CTGs operating in combined cycle (CC) mode	0.83

In evaluating ozone impacts of the emissions from the new facilities, we focused on the impacts on the MDA8 ozone because the 4th highest MDA8 in a year is used in the calculation of the design value that is used to determine attainment status of the Waco Mazanec monitor with respect to the ozone NAAQS. Note that because we modeled ozone impacts using a the month-long June 2012 historical episode, the model results allow us to examine impacts on the MDA8 only, and do not allow us to evaluate potential impacts on ozone monitor design values or attainment status.

The ozone modeling indicated that NOx emissions from the permitted/proposed EGUs at Tradinghouse and Lake Creek are predicted to increase MDA8 ozone in McLennan County. In the June 2012 episode, NOx emissions from the Tradinghouse Realistic Emissions Scenario showed maximum MDA8 ozone impacts at the Waco monitor of 0.27 ppb when all four CTGs were run in simple cycle mode and 0.15 ppb when all four CTGs were run in combined cycle mode. For Lake Creek, the Luminant Realistic Emissions Scenario ozone impacts at Waco monitor were 0.27 ppb with both CTGs running in simple cycle mode. We also evaluated the combined impacts of the two facilities for the cases where all four Tradinghouse EGUs were operating in either simple cycle or combined cycle modes. Ozone impacts of the scenarios where both facilities are operating are summarized in Table 2-3. The maximum combined MDA8 ozone impacts from Tradinghouse and Lake Creek at the Waco monitor range from 0.50-0.53 ppb depending on whether Tradinghouse CTGs are operating in combined cycle (0.50 ppb) or simple cycle (0.53 ppb) mode.

Table 2-3. Summary of daily maximum 8-hour average (MDA8) ozone impacts at the Waco Mazanec monitor (CAMS 1037) and throughout the 4 km domain for the Luminant Realistic Emissions Scenarios. Simple cycle is abbreviated SC and combined cycle is abbreviated CC).

Facility and Operating Mode	Largest Increase in MDA8 ozone (ppb) for Luminant Realistic Emissions Scenario	
	At Waco Mazanec Monitor	Within 4 km Modeling Domain
Lake Creek: 2 CTGs operating in simple cycle (SC) mode	0.27	0.7
Tradinghouse: 4 CTGs operating in simple cycle (SC) mode	0.27	1.6
Tradinghouse: 4 CTGs operating in combined cycle (CC) mode	0.15	0.9
Tradinghouse 4 CTGs in SC Mode + Lake Creek 2 CTGs in SC Mode	0.53	1.8
Tradinghouse 4 CTGs in CC Mode + Lake Creek 2 CTGs in SC Mode	0.50	1.2

We evaluated ozone impacts away from the Waco Mazanec monitor and within the 4 km modeling domain. The maximum MDA8 ozone impact from Tradinghouse within the modeling domain is 0.9 ppb for the scenario in which Tradinghouse CTGs are operating in combined cycle mode and 1.6 ppb for the scenario in which Tradinghouse CTGs are operating in simple cycle mode. The maximum MDA8 ozone impact for Lake Creek is 0.7 ppb. The maximum combined MDA8 ozone impacts from Tradinghouse and Lake Creek range from 1.2-1.8 ppb depending on whether Tradinghouse CTGs are operating in combined cycle (1.2 ppb) or simple cycle (1.8 ppb) mode.

Ozone impacts at the Waco Mazanec (CAMS 1037) monitor during a different time period could be higher or lower depending on winds, although winds for this episode are consistent with HOTCOG's conceptual model, which indicates that winds on high ozone days at the Waco monitor are generally from the same range of directions that occurred during the June 2012 modeled episode.

HOTCOG will perform a similar analysis during 2016-17 to evaluate the ozone impacts of the Sandy Creek facility. Because the Sandy Creek facility is already on-line, actual operating patterns and continuous emission monitoring data will be used to assess ozone impacts.

2.2.6.3 Point Source Emission Trends

Emission inventories for 2006, 2008, 2010, and 2012 were used to evaluate recent trends in HOTCOG county point source emissions. The TCEQ ozone modeling inventories were used for 2006 and 2012. The EPA National Emission Inventory (NEI) is published by the EPA on a triennial basis and includes point source emissions compiled from state, local, and tribal agencies, supplemented with data from the EPA[16]. 2008 emissions were taken from the EPA 2008 NEI. 2010 emissions are facility totals from the TCEQ's STARS database. Figure 2-18 shows trends in ozone precursor emissions in the 6-county area. Point source emissions decreased from 2006 to 2008 and again from 2008 to 2010 for all three pollutants. In 2012, NOx and CO emissions continued their decline, while VOC emissions increased so that they were slightly higher than in 2006 (4.7 tpd in 2012 versus 4.3 tpd in 2006). In summary, emission inventories for the 6-county HOTCOG area show reductions in local NOx and CO emissions during the 2006-2012 period, while VOC emissions are relatively small and show a decrease during 2008-2010 and rise again in 2012.

[16] http://www.epa.gov/ttnchie1/net/2008inventory.html

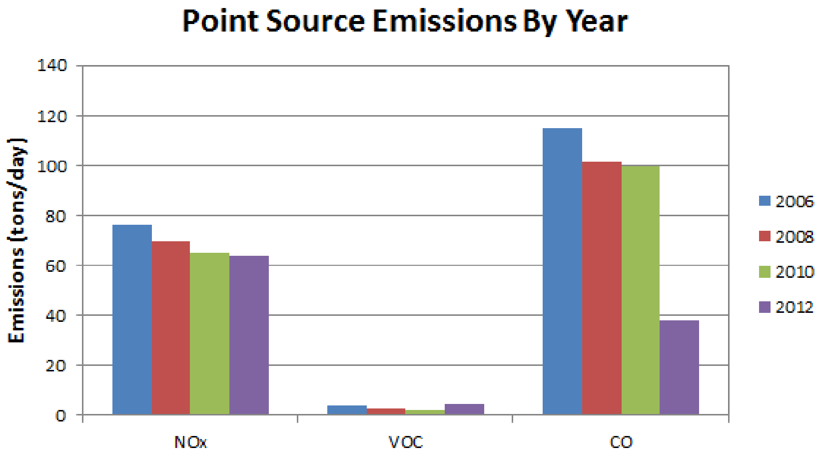

Figure 2-18. HOTCOG area total ozone season day point source emissions for 2006, 2008, and 2010.

2.2.7 Relative Importance of NOx and VOC Emissions in Ozone Formation

In order to develop emission control strategies for the HOTCOG area that will reduce the local contribution to ozone, it is necessary to understand how ozone formation in the area depends on the amount of available NOx and VOC. Ozone formation depends on the amount of NOx and VOC present as well as on the ratio of VOC to NOx, where the ratio is taken in terms of ppbC/ppb. When the VOC/NOx ratio is higher than about 10, ozone formation is limited by the amount of available NOx and reducing NOx tends to decrease peak ozone concentrations. However, if the VOC/NOx ratio is less than about 7, reducing NOx tends to increase ozone levels, and the area is said to be VOC-limited. In this situation, which can occur in urban cores of large cities, ozone is suppressed in the urban area due to titration by large amounts of fresh NO emissions. When NOx emissions are reduced, the suppression of ozone by NO is lessened and ozone increases.

We calculated the VOC/NOx ratio in the 2006 and 2012 emission inventories for the 6-county area as a whole and for McLennan County, where the Waco monitor (CAMS 1037) is located. The VOC/NOx ratios are presented in

Table 2-4. For both regions and in both years, the VOC/NOx ratio is greater than 10, which indicates that both McLennan County and the HOTCOG 6-county area as a whole are regions where ozone formation is limited by the amount of available NOx. This finding is consistent with the results of HOTCOG's ozone modeling, which also indicated that ozone formation in the HOTCOG area is NOx-limited (Section 2.4). The VOC/NOx ratios for both regions are smaller in 2012 than in 2006. This is driven by the large reduction in biogenic VOC emissions in 2012 relative to 2006. It is not clear whether this reduction is due to changes in the MEGAN model and its inputs, differences in weather in the June 2006 and June 2012 periods, actual changes in land cover or some other factor(s).

Table 2-4. VOC/NOx ratios for McLennan County and the HOTCOG 6-County Area.

Region	2006 VOC/NOx (ppbC/ppb)	2012 VOC/NOx (ppbC/ppb)
McLennan County	17.0	13.0
HOTCOG 6-County Area	24.7	16.2

2.3 Effects of Weather on Ozone Formation in the HOTCOG Area

High ozone at the Waco monitor typically occurs on days when local temperatures are high (average daily maximum temperature of 97°F), wind speeds are low and wind directions range between north-northeasterly clockwise through south-southeasterly (McGaughey et al., 2010; 2012). Wind rose plots that characterize near-surface wind speed and direction at the Waco Mazanec monitor over the 2009-2012 period are shown in Figure 2-19. In a wind rose diagram, the orientation and length of spokes indicate the frequency with which a given wind direction occurs. The spokes show the direction from which wind blows toward the monitor, and the colored bands indicate the percentage of time the winds fall in a given speed range. Two sets of wind rose diagrams are shown, corresponding to: (1) no MDA8 threshold (all days), and (2) days with MDA8 ≥ 75 ppb. 75 ppb is used as the threshold for a high ozone day because this analysis was performed before the ozone NAAQS was revised in October 2015. A new analysis which uses a 70 ppb threshold will be carried out in 2016.

The wind data used to develop the wind roses are divided into morning (6 am – 11 am) hours and afternoon (12 noon – 5 pm) hours in order to investigate whether wind shifts between morning and afternoon are present on high ozone days. For each threshold, the morning and afternoon plots are based on the same set of days, and the MDA8 ≥ 75 ppb threshold plots are based on fewer days than the no threshold plots. The number of input data points is the same for the morning and afternoon wind rose plots for each monitor and threshold (unless some wind data are missing). Because there are fewer days with very high ozone (MDA8≥75 ppb) there are far fewer days of data represented in the MDA8≥ 75 ppb plots than in the no threshold plots.

The no threshold plots for morning and afternoon (left panels of Figure 2-19) show that winds at the Waco monitor are most frequently from the south. Less frequently, winds are from the north. Only very rarely are winds from the east or west. Wind speeds are typically faster than 7 knots. Because the all days plots are strongly weighted toward days with MDA8<75 ppb, this indicates that low ozone days at the Waco monitor are characterized by relatively strong southerly winds. The strong southerly winds prevent buildup of ozone and precursors over the area, and bring clean Gulf air into central Texas. The afternoon wind pattern for no threshold days is similar to the morning wind pattern. By contrast, on high ozone days (right panels of Figure 2-19), morning winds can be from any direction and winds speeds are typically slower than 7 knots. The afternoon wind for high ozone days is typically from southeast (~54%) or northeast (~30%), with average wind speed from southeast predominantly 4-7 knots and typical wind speeds from northeast at least 7 knots but less than 11 knots. This suggests that two distinct emission source regions affect the Waco monitor.

Conditions conducive to the transport, formation, and accumulation of ozone are primarily dependent on the prevailing large-scale weather patterns. The continental-scale atmospheric circulation features during high ozone episodes at the Waco monitor for 2007-2012 were investigated using a case study approach (McGaughey et al., 2012). A surface ridge of high pressure often extended south from the Central Plains or southwest from the eastern U.S. into Texas. The ridge was typically associated with clear skies, warm temperatures, and light wind speeds at the surface. High pressure was sometimes over Texas at upper levels as well; however, northerly or zonal (i.e., east/west) flow aloft was more common. Most high ozone episodes had high ozone concentrations at monitoring locations throughout the eastern half of Texas, demonstrating the regional nature of high ozone events.

Long-range back-trajectories initiated within the daytime mixed layer suggested that the inflow of continental air into Texas at one or more layers above the surface was a necessary condition for high ozone concentrations at the Waco monitor. Figure 2-20 shows inter-state back-trajectory maps based on five-day HYSPLIT model (Draxler and Rolph, 2013) back-trajectories initiated at a height of 1 km above ground level (AGL) at 1700 CST. The five-day trajectory duration was selected to capture long-range transport not only within Texas, but also from distant areas, such as the central and southeastern U.S. The back-trajectory initialization height of 1 km AGL was used since this height approximates the middle of the afternoon mixed layer on high ozone days in the HOTCOG area (McGaughey at al., 2010a).

The back-trajectories for the 17 high ozone days at the Waco monitor are shown in Figure 2-20. The vast majority of back-trajectories indicate flow into Texas from continental regions located to the north and northeast of eastern Texas; only two back-trajectories indicated flow that originated from over the Gulf of Mexico. This is consistent with the Waco monitor wind rose analysis shown in Figure 2-19. The most common non-Texas geographic areas located in the upwind regions prior to high ozone days at the Waco monitor include northwestern Louisiana, Arkansas, eastern Oklahoma, and Missouri. Within Texas, the back-trajectory paths encompass a wide range of Texas areas located to the north, east, and southeast of the HOTCOG area.

Continental air masses transported into Texas likely contained elevated background concentrations of ozone and its precursor compounds associated with both biogenic and anthropogenic emissions. Upwind areas within Texas mostly included eastern portions of Texas east of a north-south line between DFW and Victoria; common upwind non-Texas areas were the Mississippi River Valley and geographic areas to the west such as Louisiana, Arkansas, eastern Oklahoma, and Missouri and portions of surrounding states.

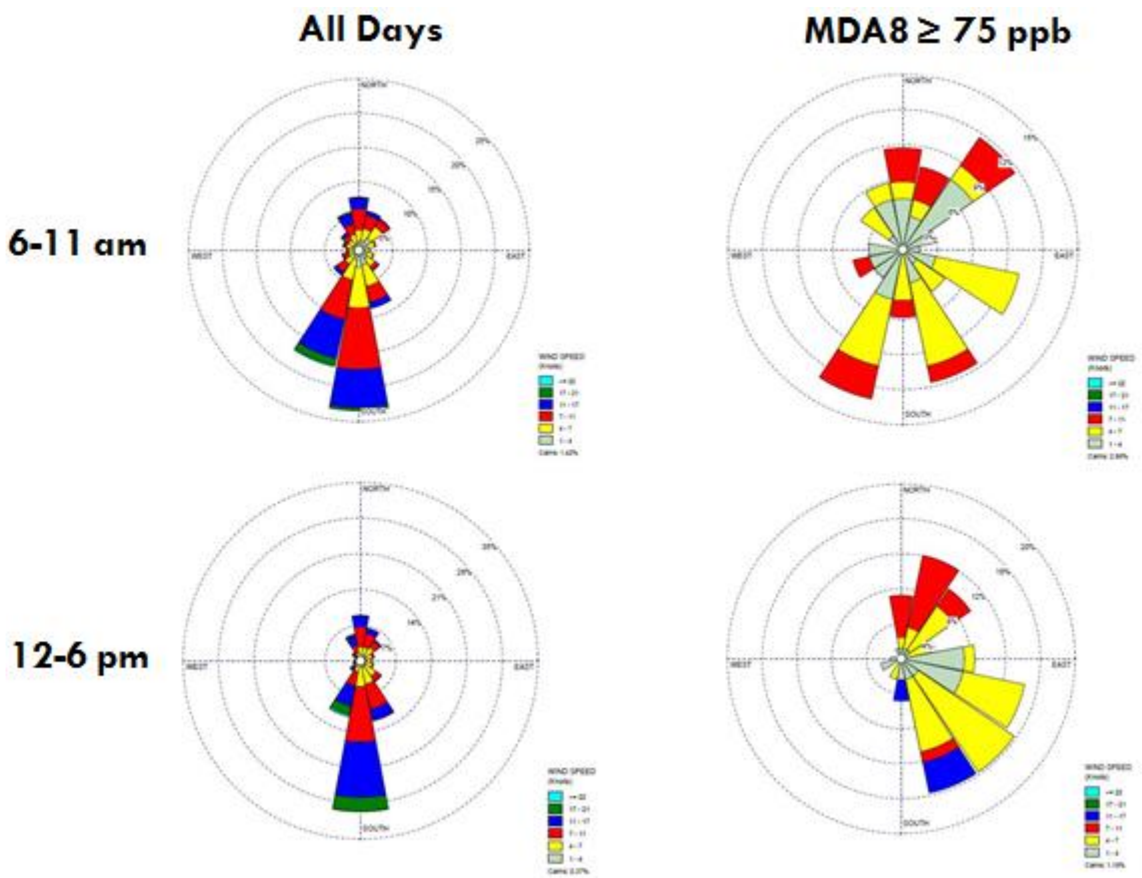

Figure 2-19. Waco wind roses for morning (upper panels) and afternoon (lower panels) on all days (left panels) and days with MDA8≥75 ppb (right panels).

McGaughey et al. (2012) found that the majority of high ozone episodes were initiated by the passage of a cold front through the HOTCOG area. Some cold fronts were accompanied by strong gusty winds and the transport of noticeably cooler air into Texas, while other cold fronts primarily represented a diffuse and ill-defined transition zone between drier continental air to the north and moister, maritime air to the south. For these latter systems, increased solar radiation and drier air were associated with increases in the daytime maximum temperatures compared to pre-frontal conditions. For a subset of episodes, the cold front stalled just to the south of the HOTCOG area so that high ozone concentrations were limited to northern Texas regions.

For some high ozone episodes, the southward movement of the surface ridge of high pressure into Texas was associated with long-range transport of continental air into the HOTCOG area from locations located well north of Texas. Other high ozone episodes were initiated when a surface high pressure ridge over eastern portions of the US expanded southwestward into Texas. For this latter scenario, the high pressure ridge was sometimes associated with a cold front that had moved south into or through the eastern U.S. during previous days and was associated with long-range transport from the northeast. A few high ozone days had inlandmoving tropical low pressure systems in the western Gulf of Mexico that may have enhanced northeasterly or easterly winds in the lower atmosphere over eastern Texas.

Overall, these analyses found that the necessary (but not sufficient) criteria for high ozone concentrations at the Waco monitor were local meteorological conditions conducive to the accumulation and formation of ozone near the surface (warm temperatures, light wind speeds) as well as the occurrence of large-scale lower-tropospheric atmospheric circulation features favorable for the long-range transport of air of recent continental (as opposed to maritime) origin into the HOTCOG area.

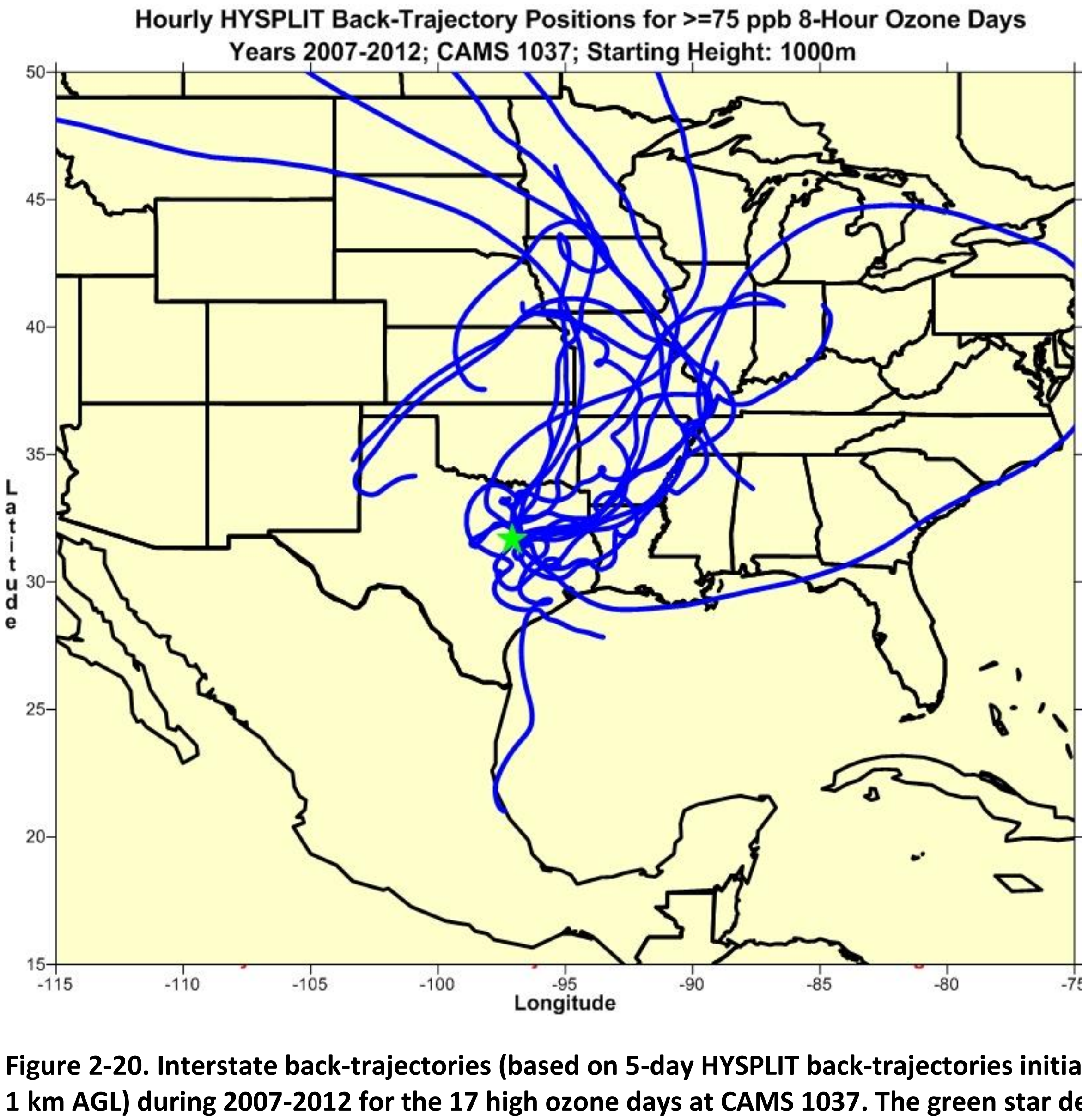

Figure 2-20. Interstate back-trajectories (based on 5-day HYSPLIT back-trajectories initiated at 1 km AGL) during 2007-2012 for the 17 high ozone days at CAMS 1037. The green star denotes the location of the Waco monitor.

2.4 Ozone Modeling

In 2010, the TCEQ began development of a June 2006 modeling episode for use by the Texas Near Nonattainment Areas. The TCEQ developed emission inventories, meteorological modeling and other inputs for photochemical modeling using the Comprehensive Air Quality Model with Extensions (CAMx; Ramboll Environ, 2016). HOTCOG ran and evaluated this 2006 base case ozone model at ozone monitors in and near the HOTCOG area, at rural monitors along the Texas border with Louisiana and Oklahoma, and at rural monitors in the Southeastern U.S. and Ohio River Valley (Kemball-Cook et al., 2014). The model performed well in central Texas, but had a high bias at Texas rural border monitors and in the Southeastern U.S. and Ohio River Valley. Note that the Waco monitor was not active in 2006, so the ozone model was evaluated at nearby monitoring sites in Temple and Italy.

Ozone source apportionment modeling was carried out with the 2006 model. Although the Waco monitor was not active in 2006, source apportionment analyses were performed for the current location of the Waco monitor. The source apportionment results showed that ozone formation in the HOTCOG area under 2006 conditions was limited by the amount of available NOx. This finding is consistent with the 2006 emission inventory analysis, which indicated that the VOC emission inventory for the 6-county area is dominated by biogenic VOC. The abundance of biogenic VOC ensures that there is always enough VOC available to form ozone so that the amount of ozone formed is determined by the amount of NOx emissions. This finding means that emission control strategy development in the HOTCOG area should focus on controlling NOx emission sources rather than VOC sources.

The ozone source apportionment results indicated that, on average, transported ozone contributed far more to HOTCOG area ozone than local sources during the June 2006 episode. Emissions within the 6-county area accounted for 10 ppb of the episode average 8-hour average ozone at the Waco monitor location, while transport accounted for 65 ppb. The local HOTCOG contribution to the daily maximum 8-hour average ozone varied from day to day depending on the wind direction, but reached a maximum of 24 ppb. The magnitude of this impact suggested that local emissions control measures can be effective in reducing ozone in the HOTCOG area.

The 2006 ozone source apportionment results were analyzed to determine which HOTCOG emissions source categories make the largest contributions to HOTCOG area ozone levels. The categories with the largest ozone impacts were on-road and off-road mobile sources, elevated point sources, and oil and gas sources.

During the summer of 2013, the TCEQ made a 2012 anthropogenic emission inventory available to Ramboll Environ for use in the development of an ozone forecasting system for the State of Texas (Johnson et al., 2013). A 2012 typical day emission inventory was developed for use with the June 2006 episode and was used to assess how emissions changes from 2006 to 2012 affect HOTCOG area ozone under the meteorological conditions of June 2006. The CAMx run using 2012 emissions in the 2006 Rider 8 modeling platform showed decreases in HOTCOG area ozone throughout the modeling episode relative to 2006 emissions. There were six days in which the daily maximum 8-hour average ozone exceeded 75 ppb in the 2006 emissions run, but no days over 75 ppb in the 2012 emissions run using 2006 meteorology. The episode average HOTCOG contribution dropped from 10 ppb in the 2006 emissions run to 5 ppb in the 2012 emissions run.

The relative contributions of transported ozone and local ozone due to emissions sources within the 6-county HOTCOG area were similar in nature using both 2006 and 2012 emissions in the June 2006 model. In the 2006 emissions run, transport contributed far more (65 ppb) to ozone at the Waco monitor than did HOTCOG area emissions sources (10 ppb). This was also true in the 2012 emissions run, in which transport contributed 53 ppb and the HOTCOG area sources contributed 5 ppb.

In March 2015, the TCEQ completed development of a 2012 modeling episode for use by the Texas NNAs. The TCEQ developed episode-specific weather data as well as an updated 2012 emission inventory. This 2012 episode now replaces the June 2006 modeling episode, as the 2006 emission inventory is now out of date. The nested 36/12/4 km modeling grids for the 2012 episode are shown in Figure 2-21. The Weather Research and Forecasting Model (WRF; Skamarock et al., 2005) was used to develop meteorological fields (winds, temperatures, pressures, precipitation) for CAMx. The 2012 episode modeling results are described in detail in Kemball-Cook et al. (2015) and are summarized below.

Figure 2-21. TCEQ 36/12/4 km CAMx nested modeling grids for the Texas ozone modeling of June 2012. 36 km grid is outlined in black. The 12 km grid outlined in blue, and the 4 km grid is outlined in green. TCEQ figure from http://www.tceq.texas.gov/airquality/airmod/rider8/modeling/domain.

Figure 2-22 and Figure 2-23 compare source apportionment modeling results from the June 2012 episode with those from HOTCOG's June 2006 ozone model (Kemball-Cook et al., 2014). In both 2006 and 2012, the contributions from NOx point source and NOx surface emissions are far larger than the corresponding contributions from VOC emissions. This indicates that ozone formation is strongly NOx-limited in the HOTCOG area in both years; this finding is consistent with the emission inventory analysis in Section 2.2.7. Both the episode average and episode maximum contributions from HOTCOG NOx and VOC emissions are lower in 2012 than in 2006. This is consistent with the 2006 to 2012 reduction in the HOTCOG NOx and VOC emission inventories shown in Section 2.2.1.

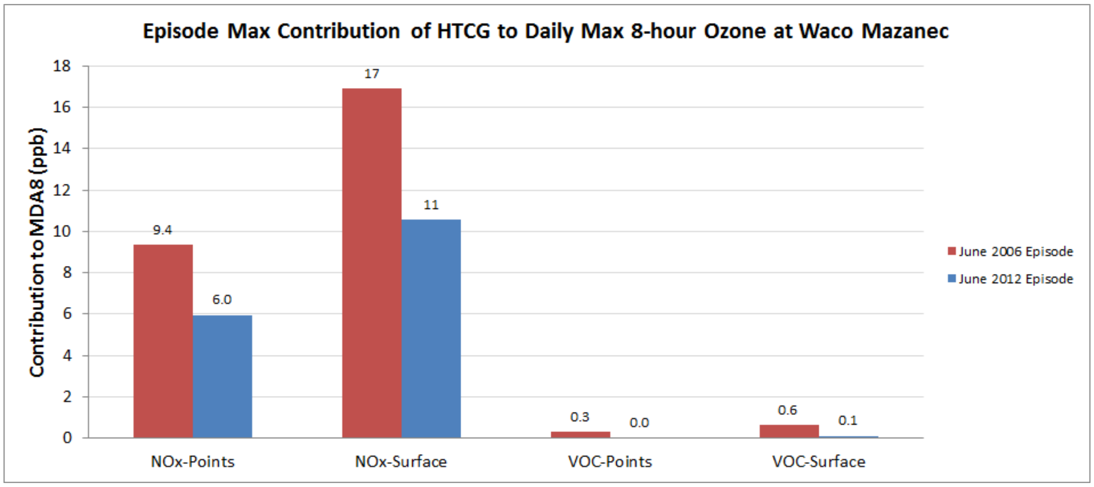

Figure 2-22. Comparison of contributions to the episode maximum 8-hour ozone at the Waco Mazanec monitor during the June 2006 and June 2012 episodes.

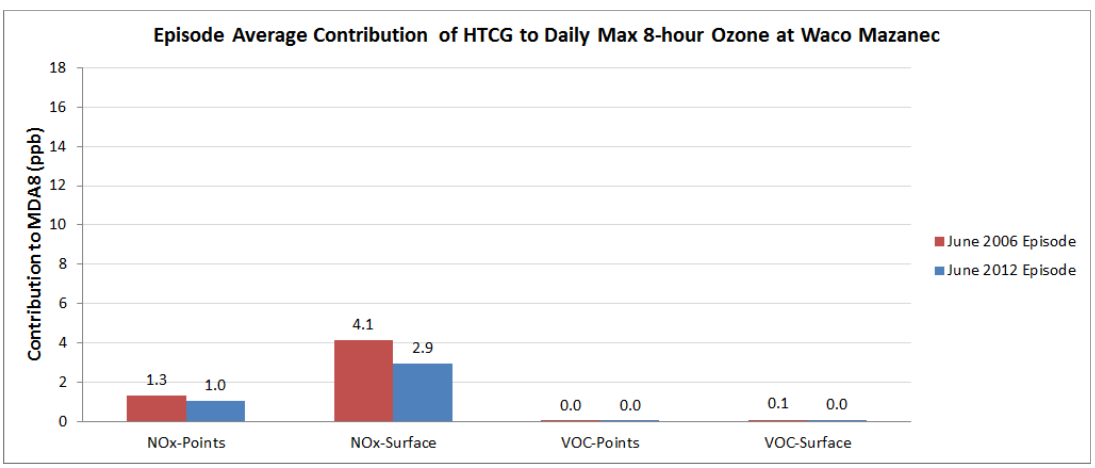

Figure 2-23. Comparison of contributions to the episode average 8-hour ozone at the Waco Mazanec monitor during the June 2006 and June 2012 episodes.

Figure 2-24 shows the June 2006 and June 2012 episode average ozone contributions to the Waco Mazanec monitor from local sources (emissions sources within the 6-county area), sources within Texas but outside the HOTCOG area, sources outside Texas, and the sum of contributions from initial and boundary conditions. The sum of contributions from initial and boundary conditions may be taken as an estimate of the contribution to HOTCOG area ozone from sources outside the U.S. and from the stratosphere. This contribution averaged 21 ppb during June 2012 and 23 ppb in June 2006. The contribution from sources within the 36 km grid and outside Texas decreased from 19 ppb in 2006 to 14 ppb in 2012. The contribution from sources within Texas but outside the HOTCOG area decreased from 23 ppb in 2006 to 14 ppb in 2012.

The relative contributions of transported ozone and local ozone due to emissions sources within the 6-county HOTCOG area were similar in nature in both 2006 and 2012. In the 2006 emissions run, transport contributed far more (65 ppb) to ozone at the Waco monitor than did HOTCOG area emissions sources (10 ppb). This was also true in the 2012 emissions run, in which transport contributed 53 ppb and the HOTCOG area sources contributed 5 ppb.

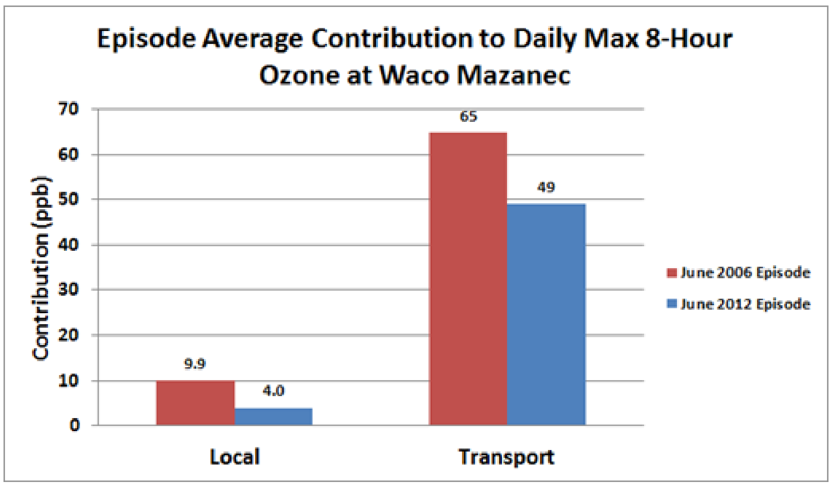

Figure 2-24. Episode average contribution to the daily maximum 8-hour average ozone at the location of the Waco Mazanec monitor.

The Waco monitor episode maximum and episode average ozone contributions from each emissions source category are shown in Figure 2-25 and Figure 2-26, respectively. Values for the June 2012 episode (solid bars) and the June 2006 episode (hatched bars) are shown. For all emissions source categories, episode maximum and episode average ozone impacts from HOTCOG area emissions sources are lower in 2012 than in 2006. This is consistent with the emissions reductions in HOTCOG area anthropogenic emissions shown in Figure 2-7 and Figure 2-8.

In June 2012, the largest value of the maximum contribution comes from the elevated point source category (6.0 ppb) and occurs on June 23. In 2012, on-road mobile sources make the largest episode maximum contribution (5.5 ppb) to MDA8 ozone at the Waco monitor followed by non-road sources (4.5 ppb). It is reasonable that the Waco monitor location should have a large maximum contribution from point sources, because point sources were the largest component of the 6-county area's 2012 and 2006 NOx emission inventories. The episode average contribution from elevated point sources is lower than that of on-road and off-road mobiles sources, despite the fact that its NOx emissions are larger. This is because contributions from elevated points are initially organized into relatively narrow plumes. Therefore, point source impacts at the monitor are dependent on the wind direction, while on-road and off-road mobile sources are distributed more evenly across the 6-county area and so make a more consistent contribution to ozone at the Waco monitor.

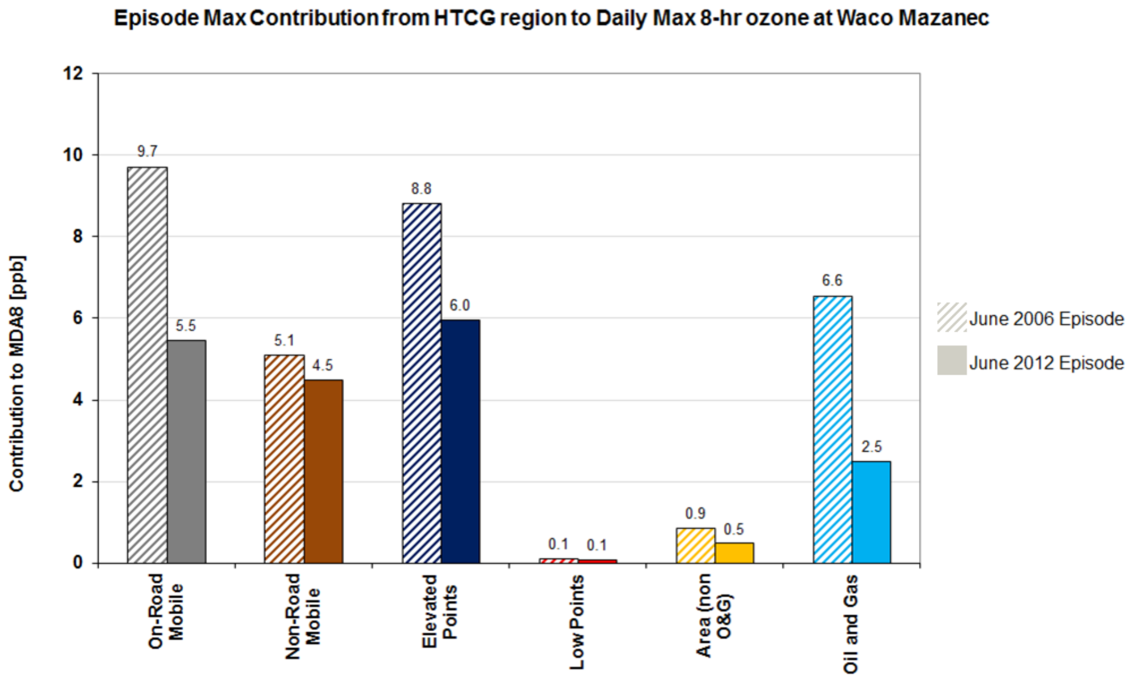

Figure 2-25. Episode maximum contribution to Waco Mazanec monitor ozone from HOTCOG 6-county area emissions for the June 2012 episode (solid bars) and June 2006 episode (cross hatched bars).

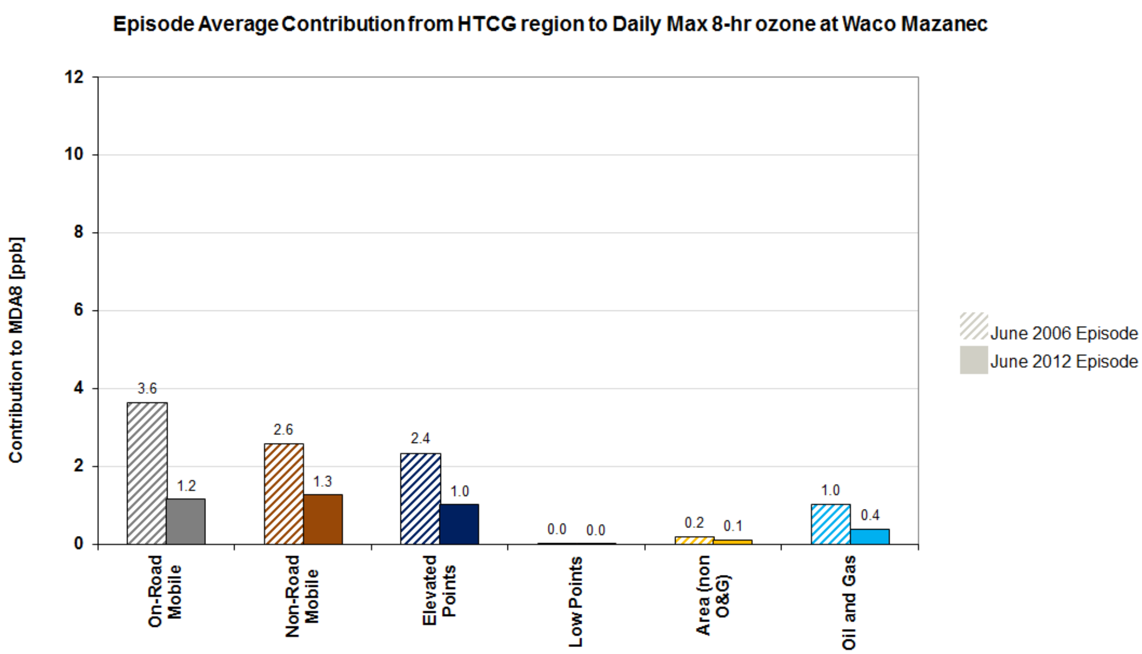

Figure 2-26. Episode average contribution to Waco Mazanec monitor ozone from HOTCOG 6-county area emissions June 2012 episode (solid bars) and June 2006 episode (cross hatched bars).

3.0 STAKEHOLDER INVOLVEMENT

3.1 HOTCOG Air Quality Advisory Committee

In January 2010, the HOTCOG Air Quality Advisory Committee (AQAC) was formed in response to the Waco area's inclusion in the Texas Rider 8 Program for Near Nonattainment Areas and the potential for a new, more stringent ozone NAAQS which could have led to the HOTCOG area's designation as a nonattainment area. Although a more stringent NAAQS was not adopted at that time, and the area remains in attainment of the NAAQS, the AQAC has worked vigorously to study local ozone air quality and to develop voluntary programs that improve air quality while protecting the vitality of the regional economy. The AQAC meets monthly and has carried out a variety of activities which are described in Section 4. The AQAC includes representatives from local government, industry, the TCEQ, and private citizens. Organizational support is provided by HOTCOG. The members of the AQAC are listed in Table 3-1.

Table 3-1. HOTCOG AQAC membership.

Falen Bohannon – Heart of Texas Council of Governments Environmental Planner
Bryan Ferguson - Mayor of Robinson
Chris Evilia - Waco Metropolitan Planning Organization
Jack Stiffler - Marathon Norco Aerospace
Alan Stover- Baylor University
Dick Van Dyke – Heart of Texas Economic Development District
Frank Patterson - Waco/McLennan County Emergency Management Coordinator
Malcolm Duncan, Jr. - Mayor of Waco
John Hendrickson - Waco Transit
Kathy French/Bill Peterson - LS Power
Kris Collins - Waco Chamber Economic Development
Matt Groveton - Limestone County Emergency Management Coordinator
Ed Kabobel – Texas Department of Transportation
Rebecca Sheesley, Baylor University
Polly Porter – Texas Commission on Environmental Quality
Randy Riggs - Private Citizen
Don Montgomery - Luminant
Steve Sharp - Falls County Judge
Trey Buzbee - Brazos River Authority
Wiley Stem - Waco City Manager

4.0 DESCRIPTION OF MEASURES AND PROGRAMS

In this section, we describe programs and measures aimed at improving ozone air quality in the 6-county HOTCOG area. These programs and measures were implemented by the HOTCOG AQAC and are either currently in place or are planned for the near future (i.e. 2016-2017).

4.1 Participation in TCEQ Rider 7/8 Program

Since 2010, the HOTCOG area has participated in the TCEQ's Rider 8 Air Quality Planning Program. The program is named after the Texas Legislature Rider under which funding was allocated. The name of the program was changed to Rider 7 in 2015 following the 2015 session of the Texas Legislature and renewal of the air quality program under a different Rider. The Rider 7 Program is designed to help Texas Near Nonattainment Areas (NNAs) maintain compliance with the ozone NAAQS. This program allows the NNAs to receive funding for their air quality planning efforts and to leverage the TCEQ's ongoing emission inventory development and meteorological and photochemical modeling.

The TCEQ has established the following goals for the Texas NNAs under the Rider 7/8 Program[17]:

- Develop a conceptual understanding of local ozone formation processes;
- Evaluate local emissions inventories developed by the TCEQ (identifying possible areas of improvement);
- Analyze local ambient air quality monitoring
- Identify local emissions controls for future in-depth study
- Assess potential local monitoring networks and recommend enhancements or special studies;
- emissions inventory improvements;
- Implement local emission control strategies;
- Use a photochemical modeling episode developed by the TCEQ to analyze ozone sources and conduct sensitivity tests
- Improve public understanding of the ozone problem and motivate the public to voluntarily reduce its contribution to ozone pollution; and
- Involve local stakeholders in local air quality planning so that these efforts have broad support within local communities.

Rider 7/8 Program activities align well with HOTCOG's participation in Ozone Advance.

4.1.1 Technical Studies Carried out Under the TCEQ Rider 7/8 Program

Under the Rider 7/8 Program, the HOTCOG AQAC has developed a conceptual model of ozone formation (McGaughey et al., 2010a, 2012; Parker et al., 2013) and made recommendations regarding the ambient monitoring network (McGaughey et al., 2010b), evaluated TCEQ

[17] http://www.tceq.texas.gov/airquality/airmod/rider8/rider8-background

emission inventories (Kemball-Cook et al., 2010) and recommended inventory improvements (Kemball-Cook et al., 2012). The AQAC has carried out a field study to examine the prevalence of heavy duty diesel vehicle idling at local truck stops (ENVIRON, 2013b) and analyzed potential local emissions control strategies (DenBleyker et al., 2013). AQAC has also performed photochemical modeling to evaluate the relative importance of ozone transport and local emissions in causing high ozone in the 6-county area, and has performed emissions sensitivity tests to evaluate the relative effectiveness of proposed local emission control strategies (Kemball-Cook et al., 2014; 2015). In 2015, the AQAC carried out photochemical modeling to assess potential ozone impacts of newly proposed/permitted EGUs in southern McLennan County (see Section 2.2.6.1). The ozone impact evaluation is an example of the effectiveness of the AQAC's stakeholder process. The AQAC identified the new EGUs as a possible concern for local air quality and initiated a study to evaluate their potential impact on HOTCOG area ozone. Many AQAC members contributed to this evaluation. For example, Luminant's representatives on the AQAC provided emissions scenarios for the ozone impact modeling and multiple members of the AQAC, including the TCEQ, the City of Waco and the Waco Metropolitan Planning Organization, provided review and comments on the photochemical modeling report prepared by Ramboll Environ.

Current technical activities funded through the Rider 7 Program include a detailed evaluation of the TCEQ 2012 emission inventory for the HOTCOG area, an update of the HOTCOG conceptual model for ozone, and photochemical modeling of the 2012 ozone season. The Rider 7/8 program also provides funding for the measures and programs described in Sections 4.1.2 through 4.1.5 below.

4.1.2 Emissions Reduction Measure: Gas Compressor Engine Retrofits

The HOTCOG AQAC's emission inventory analysis, photochemical modeling and control strategy evaluation (DenBleyker et al., 2013) work indicate that control of NOx emissions from compressor engines associated with natural gas production can reduce the local contribution to ozone in the 6-county area. Stationary gas compressor engines are distributed throughout active gas well sites in Freestone, Limestone and Hill Counties (Figure 2-12). Gas compressor engines typically run continuously for 24 hours per day throughout most of the year. Based on survey data collected by the TCEQ from Barnett Shale gas well operators[18], it seems likely that many of these engines are rich-burn engines with no emissions control systems.

During 2015, the AQAC planned to fund installation of 3-way catalytic converters targeting NOx, CO and hydrocarbon emissions reductions on rich-burn natural gas-fired stationary gas compressor engines at gas well sites in Freestone and Limestone Counties (Lindhjem et al., 2015). The target engines were rich-burn engines under 240 hp in size and therefore exempt from the East Texas Combustion Rule, which sets limits on NOx emissions from these engines.

18 https://www.tceq.texas.gov/assets/public/implementation/air/ie/pseiforms/Barnett%20Shale%20Area%20Special%20Inventory.pdf

The study aimed to identify rich-burn gas compressor engines located at natural gas wells in Limestone or Freestone Counties with the potential to be retrofitted with an emission control device on a voluntary basis. Limestone and Freestone Counties were the focus of this effort because most of the natural gas wells in the 6-county area are located in these two counties (Figure 2-12). As an initial step in this task, Ramboll Environ conducted outreach ten oil and gas companies operating in Limestone and Freestone Counties to identify appropriate candidate compressor engines and to assess interest and willingness on the part of the oil and gas company to participate in the study. No company responded positively to the request to participate, and therefore, this emissions reduction project was cancelled.

Retrofit of gas compressor engines is the most cost-effective local NOx emissions reductions strategy available in the HOTCOG 6-county area with potential reductions of 2,920-5,840 tpy (DenBleyker et al., 2013). HOTCOG's control strategy evaluation and photochemical modeling indicate that if the cooperation of compressor engine owner/operators can be enlisted in the future, retrofitting these engines would provide substantial and cost-effective NOx emissions reductions that would reduce ozone in the HOTCOG area (DenBleyker et al., 2013; Kemball-Cook et al., 2014).

Schedule for Implementation: Project was cancelled during June 2015.

Responsible Party: All technical work was carried out by Ramboll Environ under contract to HOTCOG with funding provided through the Texas Rider 7/8 Program. Review of technical work and the report summarizing the project (Lindhjem et al., 2015) was performed by the HOTCOG AQAC and the TCEQ. Because industry partners for this emissions reduction measure could not be found, funding allotted for this measure was reallocated to the municipal fleet retrofit/replacement emissions reduction measure described below.

4.1.3 Emissions Reduction Measure: Municipal Fleet Diesel Engine Retrofit/Replacement

The HOTCOG AQAC's control strategy evaluation (DenBleyker et al., 2013) indicated that control of NOx emissions from heavy duty diesel vehicles is another cost-effective means to reduce the local contribution to HOTCOG area ozone. Selected control strategies focus on heavy-duty diesel vehicles because they emit NOx at a higher rate per mile and often drive more miles per year than light-duty vehicles. This emissions reduction project targeted replacement/retrofit of city and county fleet heavy-duty diesel vehicles (HDDV) operating within the 6-county area.

During 2014-15, HOTCOG performed outreach to city and county governments in the 6-county area requesting information on vehicles potentially suitable for replacement/retrofit. Twenty truck replacement/retrofit candidates were suggested by several project proponents. For each candidate vehicle, Ramboll Environ calculated potential NOx emission reductions from engine retrofit/vehicle replacement and the cost effectiveness in terms of cost per ton of NOx emissions. Based on this information, the HOTCOG AQAC selected the HDDV emissions reduction projects to be implemented.

The two most cost effective projects were chosen for funding, minimizing the cost per ton of NOx emissions removed. A Falls County 1998 Kenworth garbage transfer truck ($17,195/ton NOx) and a Falls County 1998 Mack dump truck ($18,512/ton NOx) were selected. Falls County provided additional funding to enable both projects. Engine retrofit was determined to be infeasible based on the age of the trucks. The two Falls County 1998 trucks were therefore identified for replacement rather than repowering. The two Falls County 1998 model year trucks were scrapped according to guidance and verification methods established by the TCEQ under the Texas Emissions Reduction Plan (TERP[19]) program. The TERP guidance requires that the decommissioning must generally be carried out by complete crushing or other complete destruction of the vehicle, equipment, or engine, or by making a hole in the engine block on both sides large enough to prevent repairs (usually at least 3 inches) and, for a replacement project, permanently destroying the frame by cutting the frame rails or main structural components of the vehicle.

The engines in the two 1998 vehicles being replaced by HOTCOG were rendered unusable and irreparable by boring a 3 inch hole into the engine block and the truck frames were cut in half prior to sale of the truck parts for scrap metal (Figure 4-1).

Figure 4-1. Holes bored into the engine blocks of the two replaced vehicles (upper panels) and severed frame rails in the two replaced vehicles (lower panels).

HOTCOG solicited bids from local dealers for the purchase of two recent model year trucks to replace the two 1998 trucks. Falls County provided additional funding to supplement the funds from HOTCOG's Rider 8 FY14-15 Program Grant Agreement (PGA) so that two vehicles could be

[19] https://www.tceq.texas.gov/airquality/terp

purchased. The two Falls County 1998 trucks were each replaced with a 2011 Peterbilt Model 367 truck meeting a NOx emission standard that is consistent with the 2015 model year and is more than 90% lower than the standard met by the two replaced 1998 vehicles. The total expected NOx emission reduction from replacement of the two 1998 vehicles is 1.5 tpy.

The two 2011 Model 367 trucks purchased were a direct replacement of the two scrapped 1998 vehicles and will be used for the same purpose, which is to pull 20-yard rock trailers. The two 2011 trucks are currently in service in Falls County. Their mileage and activity will be monitored by Falls County and HOTCOG to ensure that the type and amount of use of the trucks is consistent with those of the 1998 vehicles they replaced. This is necessary to ensure that the projected NOx emissions reductions from HDDV replacement will occur. HOTCOG will report on this follow-up analysis in the 2017 update of this Ozone Advance Action Plan.

The HDDV emissions reductions projects described above will reduce NOx emissions by 1.5 tpy in the 6-county HOTCOG area. While this reduces the amount of NOx available for ozone formation, emissions reductions in the 6-county area on a larger scale are highly desirable. The TERP is a grant program established by the Texas Legislature to reduce emissions in designated counties that are in non-attainment or near non-attainment for ozone, but many TERP programs are not currently available to the HOTCOG Counties. Enhanced participation in the TERP and/or other programs such as the TCEQ's Clean School Bus Program[20] would allow diesel engine retrofit projects on a larger scale to occur and would encourage additional NOx emissions reductions.

Schedule for Implementation: Project was completed in November, 2015.

Responsible Party: All technical work was carried out by Ramboll Environ under contract to HOTCOG with funding provided through the Rider 7/8 Program. Review of technical work and the report (Lindhjem et al., 2015) was performed by the HOTCOG AQAC and the TCEQ.

[20] http://www.tceq.state.tx.us/p2/clean-vehicles/school-buses.html

RUSH TRUCK CENTERS

Peterbilt Model 367

PRICED AT $71,000.00

2011 Peterbilt 367
Cummins ISX
450HP / OTQ
Eaton Fuller FR016210C 10 Speed OD
Stock # 62053

CONTACT INFO:

Beau Crook, Truck Sales
Call: 254-644-0441
Toll Free: 800-274-1988
Local: 254-662-7900
Fax: 254-662-7999
Sales: 254-662-7910
Parts: 254-662-7960
Service: 254-662-7940

LOCATION:

Waco
3200 IH-35 South
Waco, TX 76706

HOURS:

Mon-Fri Truck Sales: 8-5pm
Mon-Fri Parts and Service: 7:30am-6pm
Sat - Parts Only: 8am-Noon

General
Unit Type Used Heavy Duty
Make Peterbilt
Model 367
Year 2011
Mileage 497111
Stock Number 62053

Day Cab
BBC 123

Exterior
Exterior Color WHITE

Engine
Engine MFG Cummins
Engine Model ISX
Horse Power 450hp

Chassis
Wheel Base 201 inches

Tires and Wheels
Front Wheel Aluminum
Rear Tire Size 22.5 LP inches

Axle
Rear Axle Ratio 3.55
Rear Axle Suspension Low Air Leaf

Transmission
Manufacturer Eaton Fuller
Model FR016210C
Speed 10 Speed OD

Figure 4-2. Specification sheet for the 2011 model year trucks used to replace each of the two 1998 HDDV that were replaced and scrapped during HOTCOG's HDDV emissions reduction project.

4.1.4 Emissions Reduction/Public Outreach Measure: Bicycle Rack Installation Program

Replacing motor vehicle trips with bicycle trips reduces ozone precursor emissions from the motor vehicle trips saved. The AQAC determined that lack of bicycle parking is a barrier to increased bicycle commuting within the 6-county HOTCOG area. In 2015, the AQAC undertook an outreach project to create safe places for bicycle parking, thereby encouraging trips that might not be otherwise performed by bicycle.

The AQAC determined suitable locations for bicycle parking sites based on anticipated levels of use, visibility by modes of transport other than bicycle (e.g. traffic counts), and input from community leaders and stakeholders. Using Rider 8 funding administered by the TCEQ, AQAC then purchased bicycle parking racks and provided them to local communities. Racks were provided to all six HOTCOG counties, and, and it was up to the local entities to choose which style of rack would best serve their needs. Figure 4-3 shows the styles of bicycle parking racks that were selected. The local communities provided the labor to remove existing pavement from the sites, installed the bicycle parking racks, and replaced the pavement. The bicycle parking racks are used as an advertising space on which to raise public awareness about ozone air quality in the HOTCOG area.

Figure 4-3. Bike racks selected for use in HOTCOG counties.

HOTCOG advertises the availability and location of the bicycle parking facilities on its web site [21] and at local events. In order to determine the effectiveness of the program, HOTCOG staff and community liaisons observed usage of the racks on a monthly basis at various times of day and/or days of the week to determine whether usage has been increasing, decreasing or constant. HOTCOG estimated the number of bicycle trips to/from each bicycle parking site and then estimated the visibility achieved by the outreach effort. HOTCOG then estimated the number of bicycle trips to/from each bicycle parking site. Table 4-1 summarizes HOTCOG's review of bike rack usage as of October 2015.

A large number of bicycle parking racks were installed in an Independent School District (ISD) and the remainder of racks were installed by individual cities. These bicycle parking racks were placed in these locations to try and capture the most saved trips that would otherwise be performed by a motor vehicle. This encourages children to ride bicycles to school, thereby

[21] http://www.breatheeasywaco.org/bike-racks.html

saving car trips. Racks placed in cities were located within city center to encourage frequent or shorts trips to be done by bike rather than by motor vehicle. This project is not yet complete, but HOTCOG's initial bicycle rack use surveys summarized in Table 4-1 indicate that, at this time, a minimum of 102 car trips are being saved per quarter. The HOTCOG AQAC Bike Rack Project had many positive impacts including:

- positively impacting air quality,
- increasing visibility for TCEQ and AQAC air quality improvement efforts
- creating goodwill at the local level with community leaders and citizens in a direct and visible way.

Table 4-1. BIke rack locations and usage.

County	Location	Address	Type	Trip Date	Racks Used	Estimated Trips Saved	Contact
Bosque	Clifton ISD	1102 Key Ave., Clifton, TX 76634	1 PBBIKE Cedar	7/6/2015 8/10/2015 9/14/2015 10/16/2015	4 5 2 1	**12**	**Ashley Abel 254-709-6820**
Bosque	Morgan ISD	1306 Charles St., Morgan, TX 76671	1 PBBIKE Cedar	7/6/2015 8/10/2015 9/14/2015 10/16/2015	1 4 2 0	**7**	**Ashley Abel 254-709-6820**
Bosque	Cransfill Gap ISD	505 South 2nd St., Cransfill Gap, TX 76637	1 PBBIKE Cedar	7/6/2015 8/10/2015 9/14/2015 10/16/2015	3 0 1 2	**6**	**Ashley Abel 254-709-6820**
Bosque	Walnut Springs ISD	184 Ave. A, Walnut Springs, TX 76690	1 PBBIKE Cedar	7/6/2015 8/10/2015 9/14/2015 10/16/2015	2 0 1 0	**3**	**Ashley Abel 254-709-6820**
McLennan	City of Waco						**Judge Felton**
McLennan	City of Mart	112 N. Commerce, Mart, TX 76664	3 Purple BRB-8	7/6/2015 8/10/2015 9/14/2015 10/16/2015	5 3 4 2	**14**	**Henry Witt 254-876-2462**
McLennan	City of Riesel	104 N Highway 6, Riesel, TX 76682	3 PBBIKE Cedar	7/6/2015 8/10/2015 9/14/2015 10/16/2015	2 1 5 2	**10**	**Alisha Flanary 254-896-6501**
McLennan	City of Moody	606 Ave. E, Moody, TX 76557	1 Red BRB-8	7/6/2015 8/10/2015 9/14/2015 10/16/2015	1 0 2 0	**3**	**Christian Vaselka 254-548-4200**
McLennan	City of Woodway	922 Estates Dr., Woodway, TX 76710	3 PBBIKE Cedar	7/6/2015 8/10/2015 9/14/2015 10/16/2015	4 2 3 2	**11**	**Natalie Edwards 254-772-4480**

County	Location	Address	Type	Trip Date	Racks Used	Estimated Trips Saved	Contact
Freestone	Fairfield ISD	615 Post Oak Rd., Fairfield, TX 75840	1 PBBIKE Cedar	7/6/2015 8/10/2015 9/14/2015 10/16/2015	2 4 0 1	**7**	**Nicole Crawford 903-388-8742**
Freestone	City of Teague	105 S. 4th, Teague, TX 75860	4 PBBIKE Cedar	7/6/2015 8/10/2015 9/14/2015 10/16/2015	3 0 0 1	**4**	**Judy Keally 254-739-2547**
Falls	City of Marlin	101 Fortune St., Marlin, TX 76661	5 PBBIKE Cedar	7/6/2015 8/10/2015 9/14/2015 10/16/2015	6 5 3 1	**15**	**Sandra Herring 254-275-0053**
Falls	City of Rosebud	402 W. Main St., Rosebud, TX 76570	3 PBBIKE Cedar	7/6/2015 8/10/2015 9/14/2015 10/16/2015	6 2 0 2	**10**	**Keith Whitfield 254-697-1966**
Hill	City of Hillsboro						**Justin Lewis**
Hill	Aquilla ISD		1 Bronze BR16-P9				**Justin Lewis**
Hill	Mount Calm ISD		1 BR8-G2				**Justin Lewis**
Hill	Penelope ISD		2 BR14-P				**Justin Lewis**

Schedule for Implementation: installation phase of the project was completed in June, 2015. Monitoring phase of project is ongoing.

Responsible Party: The bike rack program was implemented by HOTCOG with funding provided through the Rider 7/8 Program. Review of the Bicycle Rack Program was provided by the TCEQ.

4.1.5 Public Outreach Programs

The AQAC carries out a number of public outreach activities under the Rider 7/8 Program. The AQAC maintains a public web site to facilitate public access to air quality information and updates on technical and outreach activities (http://www.breatheeasywaco.org/). The website provides information on ozone and specific actions citizens can take to improve air quality as well as contact information for citizens who would like to become more involved in addressing local air quality issues. The website shows TCEQ air quality forecasts for current and upcoming days and notes whether high ozone is expected in the Waco area during the next few days. The AQAC documents traffic on its website by counting the number of times the web site is “hit” during each quarter. HOTCOG also maintains a Facebook page dedicated to increasing public awareness about ozone. The website is updated when the TCEQ’s daily ozone forecast indicates that a high ozone day is expected for the Waco area and provides information on specific actions citizens can take to reduce ozone in the 6-county area. The website address is: https://www.facebook.com/AirQualityHOTCOG?filter=1.

The AQAC has provided air quality-themed signage for public buses in the area. Figure 4-5 shows a bus wrap for a City of Waco Public Transportation Bus. Routes for the bus are varied so that it travels in McLennan County and throughout the Waco area, and the bus is used for Baylor University events and other local special events. There is a QR code on the back of the bus that provides direct access to the BreatheEasyWaco.org website. The lifetime for the bus wrap is three years. Similar air quality-themed signage was also placed on 10 rural transportation buses with routes in the other five HOTCOG counties.

Schedule for Implementation: Ongoing.

Responsible Party: All public outreach programs are implemented by HOTCOG with funding provided through the Rider 7/8 Program. Review of outreach programs is provided by the TCEQ.

Figure 4-4. Breathe Easy Waco website.

Figure 4-5. Air-quality bus wrap on a City of Waco Public Transportation Bus.

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